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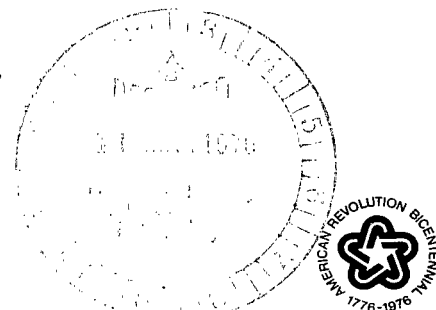
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SELECTED METHODS FOR QUANTIFICATION OF COMMUNITY EXPOSURE TO AIRCRAFT NOISE

Philip M. Edge, Jr., and Jimmy M. Cawthorn

Langley Research Center

Hampton, Va. 23665



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16. Abstract A review of the state of the art for the quantification of community exposure to aircraft noise is presented. Included are physical aspects, people response considerations, and practicalities of useful application of scales of measure. Historical background up through the current technology is briefly presented. The developments of both single-event and multiple-event scales are covered. Selective choice is made of scales currently in the forefront of interest and recommended methodology is presented for use in computer programming to translate aircraft noise data into predictions of community noise exposure. Brief consideration is given to future programming developments and to supportive research needs.					
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SELECTED METHODS FOR QUANTIFICATION OF COMMUNITY EXPOSURE TO AIRCRAFT NOISE

Philip M. Edge, Jr., and Jimmy M. Cawthorn
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SUMMARY

This paper presents a review of the state of the art of the quantification of community exposure to aircraft noise. Included is a discussion of the parameters which enter into the problem and increase its complexity – such as the noise source and propagation path components as well as the particular characteristics of the receiver. The paper traces the historical development of single-event scales such as A-weighted sound pressure level (L_A), perceived noise level (PNL), effective perceived noise level (EPNL), and D-weighted sound pressure level (L_D). Also, the development of multiple-event indexes such as composite noise rating (CNR), noise exposure forecast (NEF), equivalent sound level (L_{eq}), day-night level (L_{dn}), and the aircraft sound description system (ASDS) is presented.

Recommended ratings for incorporation into the Langley Aircraft Noise Prediction Program are formulated. The ratings selected are those which are currently in the forefront of usage or are considered to be contenders as future standards. The selected ratings include L_A , L_D , EPNL, L_{dn} , NEF, and ASDS. Also presented in the paper are several research areas which have been identified as needing further study to improve the state of the art of aircraft noise quantification.

INTRODUCTION

This paper is part of a technology assessment to establish computer automated means for translating aircraft engine and airframe data into useful predictions of noise exposures due to aircraft operations which can be incorporated in the NASA Aircraft Noise Prediction Program. Included in the computer program are modules to predict generated noise at the source, to account for atmosphere effects on the propagation of the noise, and to express the noise received at the ground as a quantitative descriptor of noise exposure. This latter part, which quantifies the noise exposure, is covered by this paper. In this part of the program, predicted noise in the form of 1/3-octave-band time histories of sound pressure level is the input. These sound pressure levels are put into

formulas for computer calculation of noise exposure in scales and indexes designed to correlate with responses of people and with community acceptance.

It is noted that there is a lack of standardization in terminology used for describing aircraft noise exposure. Therefore, the terms scale and index as used in this paper are defined as follows:

Scale	physical parameters of sound plus factors which account for psycho-physiological responses of an individual to single-event noise exposures
Index	scale plus factors associated with cumulative effects of multiple-event noise exposures

In quantifying the noise exposure, a major challenge is the task of obtaining a single descriptor that adequately provides an evaluation of the complete impact of aircraft-generated noise exposure. Historically, proposed scales and indexes have been numerous and many have found useful application in fulfilling specific needs. Satisfying these needs has reflected progress; however, at the same time the increasing number of such scales and indexes has also led to a loss of creditability for any single one. The resulting plethora of descriptors has resulted in considerable confusion. Yet among the many proposed there are several which are currently in the forefront of aircraft noise activity. It is primarily with these several scales and indexes that the Aircraft Noise Prediction Program is concerned.

This paper reviews some fundamental needs and associated requirements of aircraft noise exposure scales and indexes. The historical background of noise descriptor developments is briefly explored and the current state of the art is indicated. Selective choice is made from scales and indexes currently in the forefront, associated formulas are presented, and recommended methodology is set forth for calculation of predicted noise exposures in terms of the selected descriptors. Based on these initial program efforts brief consideration is given to supportive research needs.

ABBREVIATIONS AND SYMBOLS

ANOPP	Aircraft Noise Prediction Program
ASDS	aircraft sound description system
B	total noise load (The Netherlands)
CNEL	community noise equivalent level

CNR	composite noise rating (United States)
EPA	U.S. Environmental Protection Agency
EPNdB	unit of effective perceived noise level
EPNL	effective perceived noise level
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
HNL	hourly noise level
ICAO	International Civil Aviation Organization
L_A	A-weighted sound pressure level
L_D	D-weighted sound pressure level
L_{dn}	day-night level
L_{eq}	equivalent sound level
L_{NP}	noise pollution level
NACA	National Advisory Committee for Aeronautics
NASA	National Aeronautics and Space Administration
NEF	noise exposure forecast (United States)
\overline{NI}	noisiness index (South Africa)
NNI	noise and number index (United Kingdom)
\mathcal{N}	isopsophic index (France)

PNdB	unit of perceived noise level
PNL	perceived noise level
PNLT	tone-corrected perceived noise level
\bar{Q}	mean annoyance level (Germany)
SAE	Society of Automotive Engineers
WECPNL	weighted equivalent continuous perceived noise level (ICAO)

PROBLEM DEFINITION

A foremost requirement in the quantification of aircraft-generated noise exposure is that the descriptors used be closely correlated with people responses and with community acceptance. Moreover as with other noise control activities, the characteristics of both the noise sources and the noise propagation path must also be considered. Experience has shown that for aircraft noise control many of these special characteristics are difficult to quantify in terms of their relationship to community noise exposure.

Noise Source and Path Characteristics

For aircraft the two primary sources of noise are the propulsion system and the aerodynamic-airframe interactions. The aircraft propulsion system is itself a complex source of acoustic energy. For example, the turbofan engine has internal sources such as compressor-blade interactions and combustion processes. These sources produce noise which emanates from the engine nacelle in characteristic directivity patterns. Like the turbojet, the turbofan engine also has a major source of noise in the external mixing of the exhaust flow. In general, high-frequency-noise sources are located near the nacelle exit and low-frequency-noise sources downstream in the exhaust flow. In addition to the engine itself, some aircraft propulsion systems include drive trains, gear boxes, propellers, and rotors, each of which have special noise generation characteristics.

As noise generators, these propulsion mechanisms are sensitive to pilot operations and control (power settings and fluctuations) along with local atmospheric variations. Noise characteristics of the propulsion systems are further complexed in advanced aircraft which achieve lift as well as forward speed from the propulsion system. Helicopters using rotor systems and STOL vehicles using lift augmentation systems are examples. Newly recognized as an important noise source is the interaction of the

aerodynamic flow with the airframe; included are airflow interactions with the fuselage structure (especially wide body transports), flaps, and landing gear. Although airframe noise is generally below propulsion-system noise, additional attention must be given to the airframe noise as successful reductions of the engine noise sources are achieved. Special characteristics of airframe noise are associated with directivity and spectral content.

Very important characteristics of the aircraft as a noise source are associated with the forward speed of the aircraft. Because of the forward speed, the mechanisms of noise generation are operating in an airflow situation which may produce noise characteristics somewhat different from those produced in a stationary situation. These mechanisms of noise generation form a powerful moving noise source with rapidly changing position and distance relative to the receiver of the noise. Thus, the path between the source and the receiver is continually changing and may not be closely repeated from operation to operation.

In addition to the movement of the noise source, the path of the propagated noise is through an atmosphere which is nonhomogeneous in physical characteristics. Furthermore, these physical characteristics of the path are themselves frequently changing and thereby provide an erratic medium for the noise to propagate through. Lack of data on the detailed physical characteristics of this atmospheric path results in assumptions which may yield noise prediction errors which are difficult to separate from other errors.

Noise Exposure Description Factors

The special physical characteristics associated with aircraft noise sources and paths may to some extent be sensed by the people who are receivers of the noise. Thus, their subjective responses may be influenced. The receiver is often a nonparticipant and nonbeneficiary of aircraft operations; consequently he is frequently a hostile receiver with a reluctance to accept aircraft noise as part of his everyday environment. Therefore, in addition to describing the physical characteristics of aircraft-generated noise exposure, a meaningful unit must account for other environmental or background noises and be sensitive to the subjective responses of people. For example, aircraft noise in the presence of other background/environmental noises may be received quite differently from aircraft noise alone because of differing responses to the combined characteristics of the total noise exposure.

As indicated, the physical descriptors of noise exposure must account for both the aircraft-generated noise and the noise from other sources. Physical characteristics of aircraft-generated noise include intensity level, spectra, tones, duration, time-history

parameters, spatial distribution, number of occurrences, and temporal distribution. Physical characteristics of other-source noise include intensity level, spectra, temporal distribution, and spatial distribution. In manipulating measures of these physical descriptions of noise exposure, energy summation techniques are frequently used to account for multiple-event aspects of the exposure.

In addition to physical characteristics of noise exposure, there are subjective effects and cognitive meanings which must be accounted for by a valid descriptive scale of noise exposure. For this reason, it is important that the noise measuring scales account for responses of people in their everyday living environment and activities. To some people living in an area of aircraft-noise exposure, aircraft-noise events may be quite acceptable, whereas an infrequent visitor to the area may find such noise events especially intrusive and even startling.

Upon associating the intrusive sound with the operations of aircraft, the individual may have concerns for safety and well being. These concerns may be attributed to realizations that this is a powerful noise source which is moving along an untracked path of motion. Also there may be an association with some recent news accounts of an aircraft accident. In turn the individual may experience emotional feelings of anxiety or fear, and these feelings may dominate his annoyance due to the aircraft noise. These considerations along with the physical characteristics of noise exposure must be accounted for in measuring scales to correlate adequately with annoyance-type responses of people.

The indexes should closely correlate with responses ranging from minor annoyance to health problems such as hearing loss. Included are responses associated with speech and listening interference and the degrading of sleep and relaxation activities. Although these adverse effects of noise are recognized as annoying, man's ability to adapt often results in some unawareness of noise-exposure effects which may be detrimental to his quality of life. Known or unknown, noise effects over extended time periods may have an important impact on man's everyday living activities. Thus, there is the requirement for indexes to properly account for cumulative effects of all noise exposure (aircraft and other) associated with man's activities.

The noise rating scale (or index) should meet requirements essential for its practical use. It should be sensitive to changes in noise characteristics and it should provide useful predictive capability. It should be a valid and reliable scale which properly accounts for physical parameters with a minimal measurement error. In fulfilling these requirements, the scale should not compromise by excluding necessary noise exposure or aircraft operational data. Yet, the scale should be expressed as a direct and simple measure, not requiring extensive instrumentation or analysis equipment. As an acceptable scale, it must be able to withstand pernicious challenges such as those which may

occur in a court of law or may result from political pressures; therefore, it must be based on a strong data base that is well established with a minimum of arbitrariness or unproven hypotheses.

Current Status

For nearly two decades, development has been underway to obtain an acceptable descriptor of aircraft noise that meets the requirements discussed in the preceding section. This development has been an extremely difficult task in view of the complexity of the noise source; the importance to the noise receiver (the individual in the community) of emotional, economic, political, educational, physical, and other related factors; the large range of considerations that should be accounted for in the descriptor; the variety of applications for which the descriptor will be used; and the lack of any reliable established criteria to provide a means of evaluating proposed descriptors.

The ideal descriptor has not yet been recognized. However, considerable progress has been made in developing both single-event measuring scales and multiple-event indexes. Single-event scales have been developed for important application in the acoustic evaluation of aircraft and in the noise certification of aircraft. Single-event scales also serve as a basic element of multiple-event indexes, which may include the addition of terms to account for the total noise exposure including the flight operations. Multiple-event indexes have been developed for application as descriptors of community noise exposure for airport planning, land use planning, and airport noise regulation. Although some descriptors have proven to be clearly inferior to others, no one descriptor has emerged to be clearly superior to others, either for a single event or multiple events.

HISTORICAL DEVELOPMENTS

Research into the effects of noise on people and the response of people to noise began in the 1930 time period and was highlighted with the introduction of jet aircraft in the 1950's. Descriptors to assess the effects of a single aircraft flyover (single event) were first developed to be followed by descriptors of community response to daily airport operations (multiple events). This section traces the historical development of these descriptors and is divided into two parts – the single-event descriptors and the multiple-event descriptors.

Single Event

The development of methods for the assessment of human response to aircraft noise can be traced back to early psychoacoustical experiments which were conducted in studies of the loudness of sounds. Equal loudness contours developed by Fletcher and

Munson (ref. 1) in 1933 formed the basis for the standard A-, B-, and C-weighting networks later incorporated into sound level meters. The A-weighting which is illustrated in figure 1 was developed to approximate the response of the human ear for low levels (less than 55 dB) with the lower frequencies being attenuated; therefore, greater emphasis is allowed to be given to the higher frequencies where the ear is most sensitive. The B- and C-weighting networks were originally employed for higher levels. (A historical résumé of the development of the sound level meter is contained in ref. 2.)

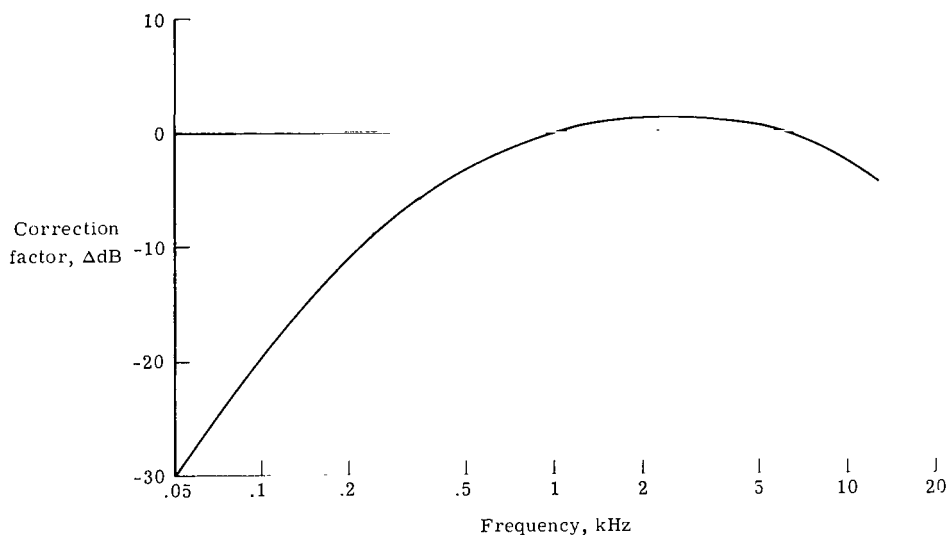


Figure 1. - A-level weighting correction factors.

Research into the quantification of the subjective attributes of sound (such as loudness, noisiness, and annoyance) has continued in both the United States and Europe by many researchers since the original work of Fletcher and Munson. During 1943, at the Harvard Psychoacoustics Laboratory under the direction of S. S. Stevens, equal loudness and equal annoyance contours were obtained (ref. 3). Under the sponsorship of The Port of New York Authority and the U.S. Public Health Service in 1959, Kryter introduced the concept of perceived noise level and developed equal noisiness contours and a calculation scheme based on previous contours and procedures developed by Stevens for calculating loudness (ref. 4). In the early 1960's, studies by Kryter and Pearsons (refs. 5, 6, and 7) resulted in further refinements to these equal noisiness contours. Illustrated in figure 2 are the currently accepted equal noisiness contours for use in computation of perceived noise level. Other researchers such as Wells (ref. 8) and Ollerhead (ref. 9) have made contributions to the understanding of subjective responses to aircraft noise. However, a review by Stevens has suggested that all the computational methods could be collapsed without significant loss of accuracy into a new procedure called perceived level of noise

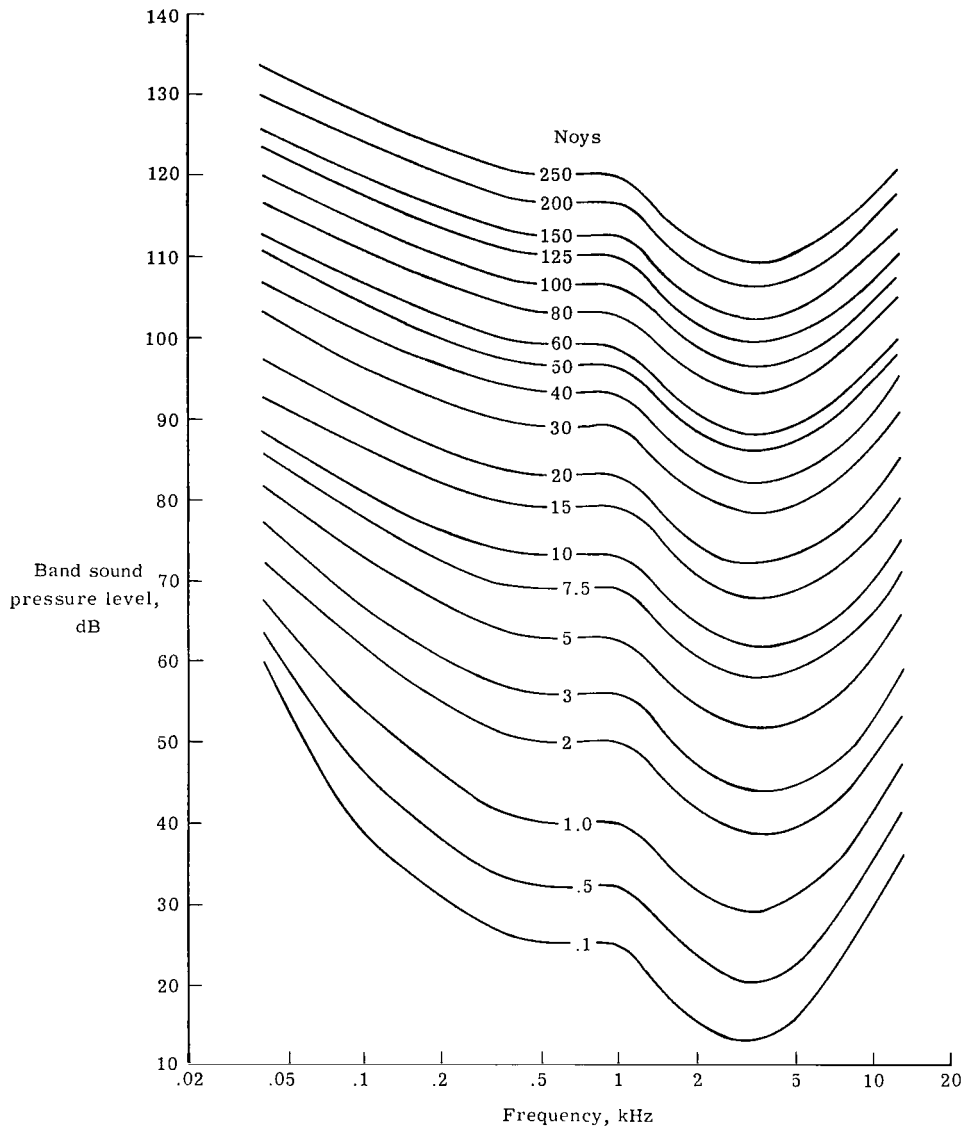


Figure 2. - Contours of equal noisiness sensitivity of the human ear.
(From ref. 5.)

by Mark VII (ref. 10). These contours are shown in figure 3, and while of considerable scientific interest, they have not replaced the noy contours in accepted methods of computing perceived noise level.

Figures 2 and 3 show the interrelation of sound level and frequency in that a given contour is judged to be subjectively equal across its frequency spectrum even though the band level changes significantly. That is, a low-frequency (100 Hz) sound must be at a

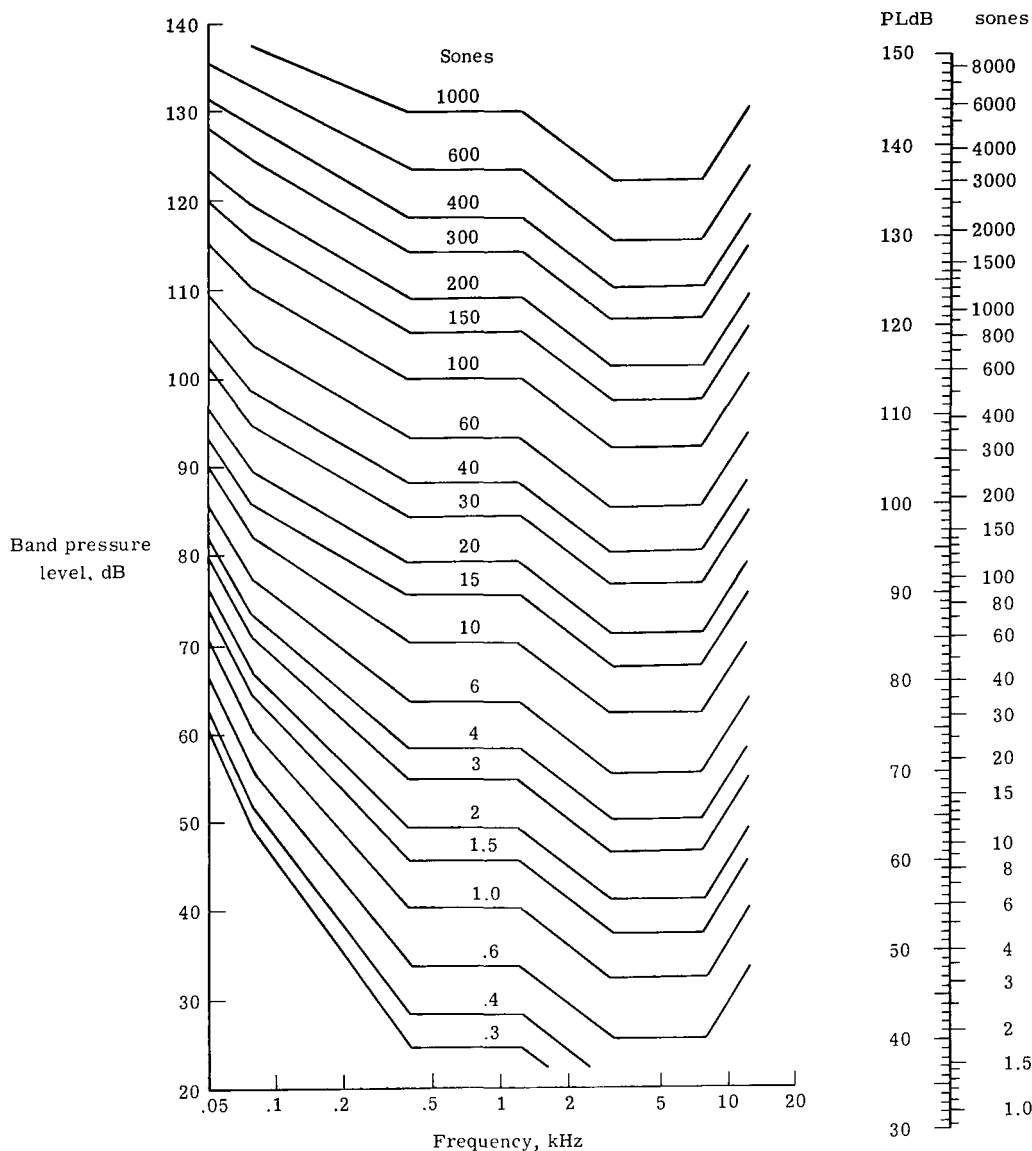


Figure 3.- Contours of equal perceived magnitude in sones. On the right is a nomogram relating magnitude in sones to perceived level in PLdB. (From ref. 10.)

higher level of intensity to sound equally loud or equally noisy as a higher frequency sound (2000 Hz).

The describing parameter of the original equal loudness curves of Stevens was called the sone. In an effort to distinguish the new noisiness concept from loudness, Kryter named the noisiness contour unit the "noy" and coined the term perceived noise level, PNL (in units of PNdB), as the name of the calculated annoyance descriptor. In calculating the PNL, a weighting scheme was used whereby sounds at frequencies at

which the ear is most sensitive were weighted higher than sounds at the less sensitive frequencies of the ear. The PNdB unit translated the subjective noy scale into a dB-like scale; that is, a doubling of the subjective noy value increased the PNL value by 10 PNdB.

In the mid-sixties, as a result of a considerable amount of research sponsored by NASA and the FAA, corrections to PNL for pure-tone components and noise duration were established; thus the effective perceived noise level (EPNL) scale in units of EPNdB was produced. EPNL became a "standard" when the FAA issued Federal Aviation Regulation Part 36 (FAR 36) in 1969 (ref. 11) and designated EPNdB as the unit to be used in the certification of new subsonic transport category airplanes.

In the early 1970's interest was renewed for the use of L_A as a scale for aircraft-noise monitoring purposes where a simplified scale was desired instead of the complicated computation procedure of EPNL. For example, in the early 1970's, "Noise Standards" for the regulation of airport noise were enacted by the state of California using L_A as the basic noise measure (ref. 12). Also, in 1973 the FAA issued a Notice of Proposed Rule Making 73-26 for the certification of general aviation (propeller-driven) aircraft which specified L_A as the measurement unit.

In an effort to develop an easily obtained unit which would more closely represent human responses to aircraft noise the scale L_D has been proposed as an alternate to L_A (ref. 13). The L_D weighting is the inverse of the 40-noy curve (fig. 2) and it has been proposed that L_D become a standard and be incorporated in commercial sound level meters. The D-level weighting is compared with the A-level weighting in figure 4.

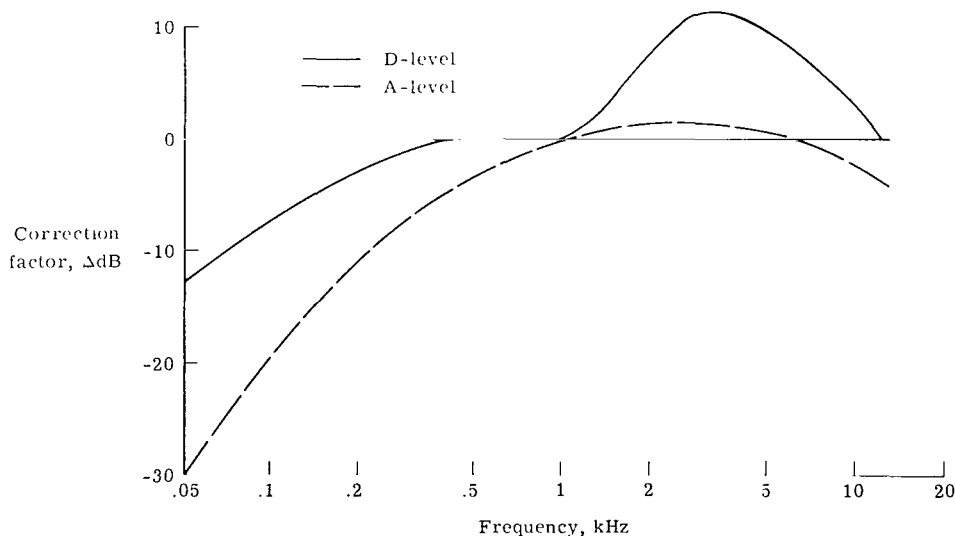


Figure 4. - Comparison of D-level weighting and A-level weighting correction factors.

Multiple Events

In the United States, the evolution of methods for assessing the impact of multiple aircraft-flyover events on an airport neighborhood community began in the early 1950's. Galloway and Bishop (ref. 14) presented a historical résumé of the development of noise exposure forecast (NEF) which is one of the established, venerable indexes. They also described how NEF relates to various noise exposure indexes developed in several other countries. The salient features of the development process as reported in that reference are given herein.

In the early and mid-1950's, the composite noise rating (CNR) concept was developed at Bolt Beranek and Newman to predict the expected community response to a noise source (refs. 15 and 16). Modifications were made to the CNR procedure in the late 1950's which enabled the prediction of community response to a combination of a series of turbojet aircraft operations (ref. 17). Up until this time the aircraft-noise-rating research studies were primarily concerned with the jet aircraft operated by the military, and most of the research studies were conducted under the auspices of the U.S. Air Force with some support from NACA (predecessor of NASA). In the early 1960's with the introduction of commercial jet aircraft, aircraft-noise-rating research studies were supported by both NASA and the FAA. By 1963 and 1964, both military and commercial aircraft operations were included in the CNR procedure and the perceived noise level concept was used as the descriptor of an aircraft noise source. This work was performed by Bolt Beranek and Newman, Inc. (ref. 18).

The NEF was introduced in 1967 by Bishop and Horonjeff (ref. 19) and at the same time by the SAE Committee A-21 under the support of FAA. The primary difference between the NEF and the CNR is that in the NEF procedure the EPNL (rather than PNL) is used as the noise stimulus descriptor and a larger constant is subtracted from the computed level. This results in a numerical value significantly different from any other index so that there is no chance of confusing NEF values with any other quantity.

While the CNR and NEF were being developed in the United States, a number of independent multiple-event airport community noise assessment measures were being developed in Europe and elsewhere. These included noise and number index, NNI (United Kingdom), isopsophic index, N (France), total noise load, B (The Netherlands), mean annoyance level, \bar{Q} (Germany), and noisiness index, \bar{NI} (South Africa). Additionally, the International Civil Aviation Organization (ICAO) formulated a measure of their own (weighted noise exposure level (WECPNL)). These indexes as well as CNR and NEF are compared in the following equations for daytime events only (after ref. 14):

$$\text{CNR} = 10 \log 10^{\text{PNL}/10} + 10 \log N - 12 \quad (1)$$

$$\text{NEF} = 10 \log 10^{\text{EPNL}/10} + 10 \log N - 88 \quad (2)$$

$$\mathcal{N} = 10 \log 10^{\text{PNL}/10} + 10 \log N - 30 \quad (3)$$

$$\text{NNI} = 10 \log 10^{\text{PNL}/10} + 15 \log N - 80 \quad (4)$$

$$\bar{Q} = 13.3 \log 10^{\text{PNL}/13.3} + 13.3 \log N - 52.3 \quad (5)$$

$$\bar{\text{NI}} = 10 \log 10^{L_A/10} + 10 \log N - 39.4 \quad (6)$$

$$\text{WECPNL} = 10 \log 10^{\text{EPNL}/10} + 10 \log N - 39.4 \quad (7)$$

$$B = 20 \log 10^{L_A/15} + 20 \log N - c \quad (8)$$

These approximations are for comparative purposes only. The actual equations for computation purposes are in the appendixes. The equations used to compute each of the units are written in a modified form so that they can be directly compared. Each equation contains a factor which relates to the noise level from a single event plus another factor which modifies the single-event level to account for numbers of operations in order to produce the multiple-event measure. A comparison of these eight equations shows that they are all similar in their basic concepts.

In the late sixties and early seventies a concept which had previously been used with success (ref. 15) was suggested as a possible contender to form the basis of a unifying noise exposure index. This is the equivalent sound level L_{eq} , based on L_A , which is computed as an average (on an energy basis) noise level integrated over a specified period of time. As is discussed in reference 20 (the EPA "Levels Document") the concept of equivalent sound level was developed in the United States and Germany over a period of years. In the United States, equivalent level was used in the 1957 Air Force Planning Guide for noise from aircraft operations (ref. 17). In Germany, L_{eq} was introduced in 1965 as an aircraft noise impact rating. However, in the 1970's, L_{eq} came to the forefront as a noise scale, largely as a result of the noise legislation enacted by the State of California (ref. 12). This scale L_{eq} precipitated the development of hourly noise level (HNL) which is used in one method of calculating community noise equivalent level (CNEL) which is specified as a standard in California for the assessment of noise impact areas around airports. Actually, HNL is a special case of L_{eq} wherein the period of integration is specified as 1 hour. L_{eq} is also used as a basis for calculating noise pollution level (L_{NP}) developed by Robinson in the United Kingdom (ref. 21).

The L_{eq} also led to the formulation of day-night level L_{dn} which is an energy-averaged noise level integrated over a 24-hour period. The L_{dn} was developed to improve L_{eq} by adding a penalty for nighttime noises. As authorized in the Noise Control Act of 1972, the Environmental Protection Agency commissioned a task force to study various noise problems. Task Group 3, of that task force, was established under the chairmanship of Von Gierke to study the implications of identifying and achieving levels of cumulative noise exposure around airports. The report of Task Group 3 to the EPA (ref. 22) was issued in 1973, and it contained the recommendation that the EPA and other Federal Agencies should adopt L_{dn} (with L_A as the base scale) as the measure for environmental noise. It was further recommended that L_D should be considered as a replacement for L_A as soon as practical – that is, when L_D is standardized and available in commercial sound level meters. Also, the EPA "Levels Document" (ref. 20) formulates the hypothesis that long-term A-weighted sound levels (L_{eq} and L_{dn}) are the best descriptors of the effects of environmental noise in a simple, uniform, and appropriate way. This document also compares the calculation methods of L_{dn} with other measures of noise used by Federal Agencies – CNR, NEF, and CNEL.

Meanwhile, the FAA conceived an alternative approach and in 1973, published a report (ref. 23) on the aircraft sound description system (ASDS). The ASDS describes exposure to aircraft noise by the amount of time that noise levels from aircraft operations exceed a threshold of 85 dB(A). In formulating the ASDS the FAA's stated goal was to present noise data to the community such that it would be both scientifically accurate and understandable to the layman. The FAA also announced that airports would be required to report their noise data in ASDS units (ref. 24). In 1974, the FAA published a four-volume report (ref. 25) which detailed the computational techniques for applying the ASDS concept. Since the use of ASDS by airports is required by the FAA it is included herein; however, at this time substantiating research as to its validity is not available.

The three different concepts which have been developed (L_{NP} , L_{dn} , and ASDS) are illustrated by the following equations (after ref. 14):

$$L_{NP} = 10 \log 10^{L_A/10} + 10 \log N + K\sigma \quad (9)$$

$$L_{dn} = 10 \log 10^{L_A/10} + 10 \log N \quad (10)$$

$$ASDS = (Time)_{L_A > 85 \text{ dB(A)}} \quad (11)$$

These approximations are for comparative purposes only. The actual equations for computation purposes are in the appendixes. By comparing equations (9), (10), and (11) with

those of the previous methods shown in equations (1) to (8), the differences in concept can be illustrated. As discussed previously, the indexes shown in equations (1) to (8) employ the same concept of an energy summation obtained by correcting a given noise level with a factor dependent on the number of operations while L_{NP} and L_{dn} (eqs. (9) and (10)) are computed as an energy average based on an integrated level (over a 24-hour period) and ASDS (eq. (11)) is simply the amount of time that the aircraft noise levels exceed a predetermined level (i.e., 85 dB(A)).

Summary

There have been developed a number of single- and multiple-event noise exposure scales and indexes which are in contention for adoption as standards. At the present time it is not known which, if any, of the existing methods will be agreed upon as the standard measure of aircraft noise assessment. Some of the leading contenders are shown in figure 5 which also depicts the scales' interrelation. The arrows indicate that some scales are used as bases for the calculation of other scales and indexes. (For example, 1/3-octave-band spectra are used to compute L_A , which is used to compute L_{eq} , which in turn is used to compute L_{dn} .) Scales and indexes are presented in the following section for incorporation in the Aircraft Noise Prediction Program (ANOPP).

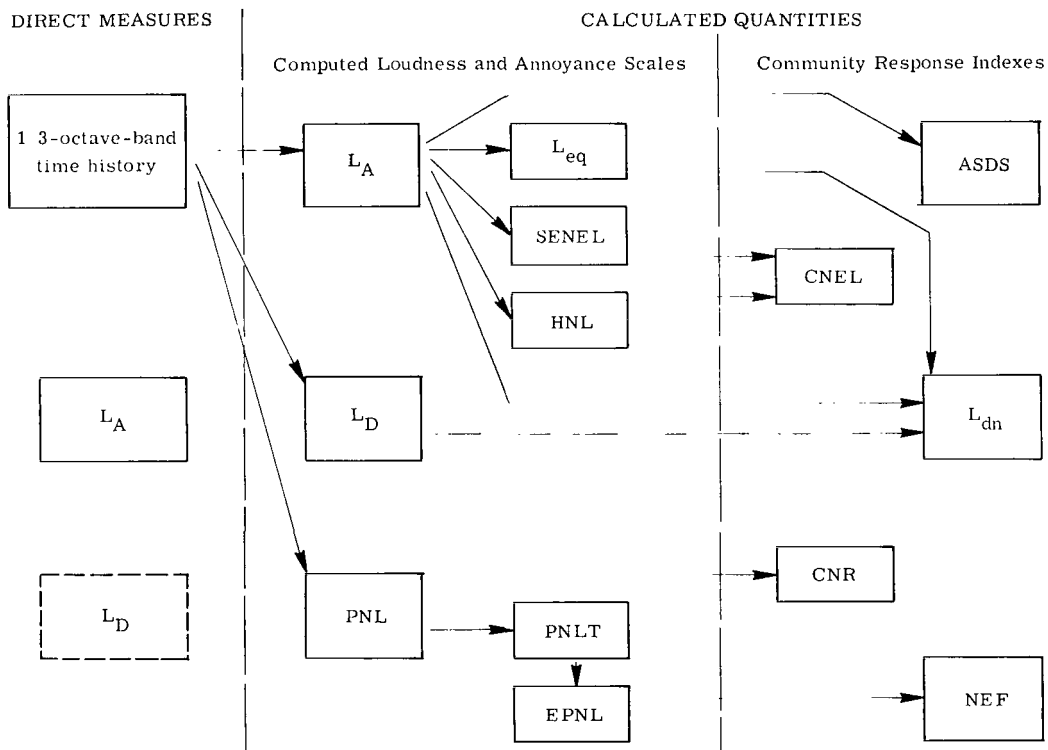


Figure 5.- Some examples of direct measures and calculated quantities used for the quantification of community exposure to aircraft noise.

METHODOLOGY

An inherent conflict-of-interest becomes apparent in attempting to formulate a rating for the assessment of aircraft noise. On the one hand, the desire is that the rating be comprehensive, include all possible variables, and consider all influencing conditions. The normal result of this desire is that as more variables are introduced the more difficult and complicated the computation procedure becomes. On the other hand, the desire is that the rating be simple to compute and easy to understand. In order to achieve simplicity some of the known variables may have to be ignored. These two concepts are naturally incompatible and it may be impossible to satisfy both desires of comprehensiveness and simplicity; therefore, some compromises may be required. This section will present some ratings which fall into each category.

There is, currently, a multitude of schemes in use for the purpose of rating aircraft noise and assessing its impact on communities but there is no agreed upon or commonly accepted "best" method. In presenting noise rating methods which can be used for assessment of human response and community exposure and impact no attempt has been made to include all the available methods. Rather, the literature was reviewed and discussions held with researchers working in this field of study and several methods were selected as appropriate for incorporation in ANOPP. Selected are those which are presently in the forefront of usage or which are considered to be contenders as future standards. Two types of rating methods were selected as shown in figure 6: Those for a

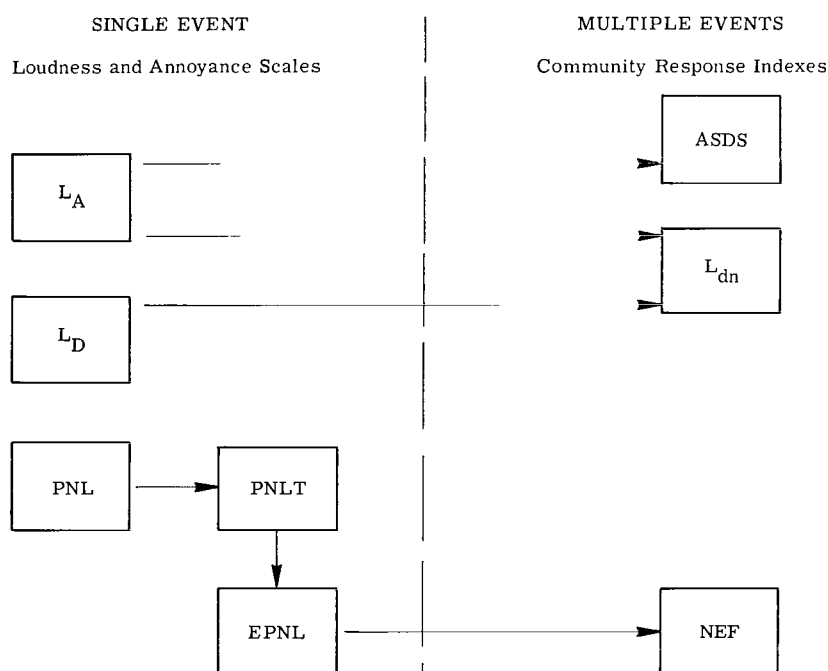


Figure 6.- Computed scales and indexes recommended for inclusion in the Aircraft Noise Prediction Program (ANOPP).

single aircraft flyover event and those for community exposure to multiple events. The prediction of aircraft noise from a single event is the primary purpose of the ANOPP; however, the critical aircraft noise problem facing the world today is the problem of the impact of the noise on people in the airport community. For this reason the capability to predict the noise exposure of multiple events must also be included in ANOPP in order to be used by those working in the area of community response and community impact of noise.

The single-event scales included are L_A , L_D , and EPNL which includes PNL and tone-corrected perceived noise level (PNLT). The multiple-event indexes are based on these single-event scales and include L_{dn} and noise exposure forecast (NEF). Additionally, ASDS which is also based on L_A is included. The reasons for including these particular scales and indexes are noted below.

A-weighted sound pressure level: A-level has at times received support as being a logical scale to use in certifying aircraft for noise and monitoring aircraft noise levels because it is a straightforward and simple measure. All commercially available standard sound level meters incorporate an A-level weighting network; therefore, A-level can be measured directly with a sound level meter and does not require any complex computations or programs to compute. A-level is the scale commonly used for industrial and traffic noise.

D-weighted sound pressure level: D-level has been recommended as a replacement for L_A as a measure of human response to aircraft noise. D-level has also been recommended as the base scale for computing L_{dn} as soon as sound pressure level meters with D-weighting networks are commercially available. Although D-level weighting networks are not yet standard on commercially available sound level meters, it is expected that in the near future D-level will be available. Also, like the A-level, D-level is determined by a simple weighting correction applied to the sound spectra and is a simple scale to compute.

Perceived noise level, tone corrected perceived noise level, and effective perceived noise level: The EPNL is the scale specified in FAR Part 36 (ref. 11) for the certification of jet transports and is an obvious choice for inclusion in the ANOPP. Since PNL and PNLT must be calculated in order to determine EPNL they must also be included. Historically, PNL has been the scale commonly used for jet aircraft noise rating.

Day-night level, noise exposure forecast, and aircraft sound description system: The indexes L_{dn} , NEF, and ASDS are currently in widespread use among several Federal Agencies in the areas of environmental pollution, land use planning, and airport community land use control.

The equations used for computing these scales and indexes are presented here in a form to make them readily incorporable into the ANOPP. Further descriptions, details, and computational methods for each are contained in appendixes A to H along with tables and curves where necessary. (Appendixes A to G are found in ref. 26, with appendix H being based on ref. 25.)

A-level:

$$L_A = 10 \log_{10} \left[\sum_{i=1}^{25} \text{antilog} \frac{\text{SPL}(f_i) + \Delta \text{dB}_A(f_i)}{10} \right]$$

where

$\text{SPL}(f_i)$ frequency-dependent 1/3-octave-band sound pressure level

$\Delta \text{dB}_A(f_i)$ A-level frequency-dependent weighting correction factor

A-level can also be measured directly with a sound level meter with an A-weighting network. (See appendix A.)

D-level:

$$L_D = 10 \log_{10} \left[\sum_{i=1}^{25} \text{antilog} \frac{\text{SPL}(f_i) + \Delta \text{dB}_D(f_i)}{10} \right]$$

where

$\text{SPL}(f_i)$ frequency-dependent 1/3-octave-band sound pressure level

$\Delta \text{dB}_D(f_i)$ D-level frequency-dependent weighting correction factor

D-level can also be measured directly with a sound level meter with a D-weighting network. (See appendix B.)

Perceived noise level:

$$\text{PNL} = 40 + 33.22 \log_{10} N_t$$

where

$$N_t = n_{\max} + 0.15 \left(\sum_{i=1}^{24} n_i - n_{\max} \right)$$

n_{\max} and $\sum n$ determined from noy tables or a mathematical formulation of
noy tables

(See appendix C.)

Effective perceived noise level:

$$EPNL = 10 \log_{10} \left[\sum_{i=0}^d \text{antilog} \frac{(PNLT)_i}{10} \right] - 13$$

where

$$PNLT = PNL + T$$

T correction for tone components

d duration of aircraft noise within 10 dB of maximum level in intervals of
1/2 second

(See appendixes D and E.)

Noise exposure forecast:

$$NEF = 10 \log_{10} \sum_i \sum_j \text{antilog} \frac{(NEF)_{ij}}{10}$$

where

$$(NEF)_{ij} = (EPNL)_{ij} + 10 \log_{10} (N_{d,ij} + 16.67 N_{n,ij}) - 88$$

i aircraft

j flight path

N_d number of daytime flights

N_n number of nighttime flights

(See appendix F.)

Day-night level:

For discrete samples of A-level for a 24-hour period

$$L_{dn} = 10 \log_{10} \left(\frac{\sum_{i=1}^n w_i \text{antilog} \frac{L_{A,i}}{10}}{n} \right)$$

where

w_i time of day weighting factor (from 0700 to 2200, $w_i = 1$; from 2200 to 0700, $w_i = 10$)

$L_{A,i}$ A-level for sample i

n number of samples of L_A in 24 hours

(See appendix G.)

Aircraft sound description system and situation index:

$$ASDS = t_{L_A > 85 \text{ dB(A)}} \text{ minutes}$$

(Applicable to 24-hour day)

$$SI = (At)_{L_A > 85 \text{ dB(A)}}$$

where

A area

t time

(See appendix H.)

The opportunity was taken to review these "forefront" formulas to determine research needed to address the defined problem of quantifying community exposure to aircraft noise. From the formulas presented and from consideration of the way these formulas may be used in the Aircraft Noise Prediction Program, specific research was identified as needed to account more adequately for nonfrequency characteristics of aircraft noise and for the background noise of the environments into which the aircraft noise

intrudes. The importance of low-frequency noise characteristics is emphasized as attention is focused on advanced aircraft using powered lift systems which may generate considerable acoustic energy at frequencies from 100 Hz to well below 50 Hz which is the lower limit of many aircraft noise descriptors. Of concern at these low frequencies is the need for the noise exposure descriptor to properly account for nonauditory responses of people in both outdoor and indoor situations. The continuing population buildup near airports and the development of short-haul aircraft operating in urban STOL ports emphasize the need for considering the background noise environment. For example, the presence of varying noise of surface transportation systems may influence the judgment of aircraft noise (ref. 27).

Apart from the scales and indexes selected as in the forefront of current activity, further research may focus increased attention on descriptors such as Robinson's noise pollution level (L_{NP}) which applies a background noise correction to equivalent sound level (L_{eq}). Also, further research is believed needed to explore descriptor systems which are not based on energy averaging or energy summation approaches. For example, the approaches of the ASDS and of Rylander and coworkers (refs. 28 and 29) are believed worthy of further study. These two approaches depend, respectively, upon time summation and upon maximum noise level event irrespective of number of events. New approaches of these types may provide a noise exposure descriptor which will make a valuable contribution to the ANOPP.

CONCLUDING REMARKS

This paper has presented a brief review of problem definition and historical developments in the quantification of community exposure to aircraft noise. From this review a number of scales and indexes have been selected as in the forefront of current usage and therefore as appropriate for incorporation into the Aircraft Noise Prediction Program. The selected descriptors include A-level, D-level, perceived noise level, effective perceived noise level, noise exposure forecast, day-night level, and aircraft sound description system. For each of these descriptors methodology has been set forth for incorporation as modules in the Aircraft Noise Prediction Program.

In considering noise exposure descriptors to be incorporated in the Aircraft Noise Prediction Program, research needs were identified to consider further low-frequency noise characteristics of advanced aircraft and community background noise effects. It was also indicated that further research consideration should be given to other descriptors as well as those based on energy averaging or energy summation.

Langley Research Center
National Aeronautics and Space Administration
Hampton, Va. 23665
November 19, 1975

INTRODUCTION TO APPENDIXES A TO H

Appendixes A to H contain additional information necessary for the computation of the scales and indexes formulated in the methodology section. Each appendix, except appendix H – ASDS, is found in reference 26. This reference is used as a source for L_A , L_D , PNL, EPNL, L_{dn} , and NEF. These scales and indexes are taken directly from that source with some slight modifications as to format and the deletion of some information discussed elsewhere in this paper. Although the ASDS (ref. 25) is not included in reference 26, it is included herein in the same format. Each appendix is subdivided into the following sections:

SCALE OR INDEX: given in its most complete form followed by its commonly referred to abbreviations

UNIT: given in preferred form followed by alternate forms

DEFINITION: gives the scope of the measure and the parameters considered

STANDARDS: includes both existing and proposed standards

GEOGRAPHICAL USAGE: indicates where the measure is most commonly used

BACKGROUND: gives a brief résumé of the development of the scale or index

CALCULATION METHOD: outlines the step-by-step procedure the user would follow to calculate the scale and this is the procedure which will be incorporated in the ANOPP

EXAMPLE: gives a typical calculation example of the scale

EQUIPMENT: lists the equipment necessary for obtaining direct measures or for obtaining data from which the scale can be calculated

REFERENCES: literature used in preparation of the appendix

APPENDIX A

A-WEIGHTED SOUND PRESSURE LEVEL

SCALE: A-level (Sound level-A, AL , L_A)

UNIT: dB(A) * (dBA , dB)

Reference pressure: $20 \mu\text{Pa}$

DEFINITION: A-weighted sound pressure level or A-level is sound pressure level which has been frequency filtered or weighted to quantitatively reduce the effect of the low frequency noise. It was designed to approximate the response of the human ear to sound. A-level is measured in decibels with a standard sound level meter which contains the weighting network for "A" shown in figure A1.

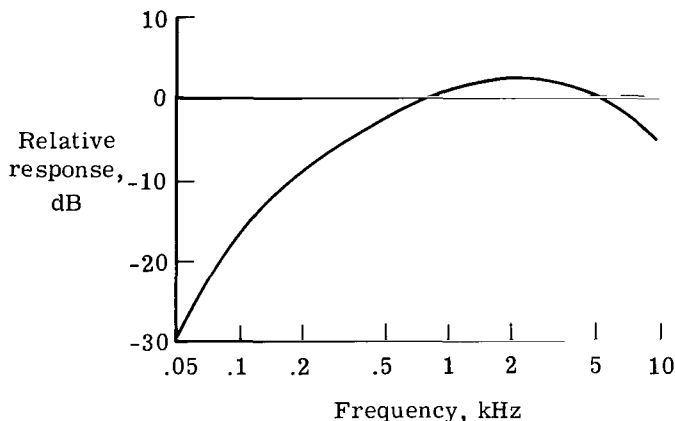


Figure A1.- A-weighting.

STANDARDS: American National Standard Specification for Sound Level Meters. S1.4-1971, American Natl. Stand. Inst., Inc., Apr. 27, 1971.

Precision Sound Level Meters. IEC Recomm. Publ. 179, Second ed., Int. Electrotech. Comm., 1973.

Recommendations for Sound Level Meters. IEC Recomm. Publ. 123, First ed., Int. Electrotech. Comm., 1961.

Octave, Half-Octave and Third-Octave Band Filters Intended for the Analysis of Sounds and Vibrations. IEC Recomm. Publ. 225, First ed., Int. Electrotech. Comm., 1966.

GEOGRAPHICAL USAGE: International

BACKGROUND: Because overall sound pressure level did not correlate well with human assessment of the loudness of sounds, weighting networks were added to sound level meters to attenuate low-frequency noise in accordance with equal loudness contours. One of these weighting networks was designated "A" and was originally employed for sounds less than a level of 55 dB. Now A-level is used for all levels.

The A-weighting is realized by a simple electrical network which provides the weighting shown in figure A1. A-level has been found to correlate well with people's subjective

*The official unit for all the weighted sound levels is dB; however, it is often seen in literature as dB(A) , etc.

APPENDIX A

judgment of the annoyance of many types of noise. Its simplicity and superiority over unweighted SPL in predicting people's responses to noise has made it a widely used measure.

CALCULATION METHOD: A-level can be determined with a sound level meter that contains an electrical network for A-weighting. A-level also may be estimated by applying A-weighting values (table AI, fig. A1) to octave or 1/3-octave frequency band measures and summing the bands on the basis of their squared pressures (often referred to as summation on an energy basis).

TABLE AI - A-WEIGHTING CORRECTION FUNCTIONS

1/3-octave-band center frequency, Hz	Octave- and 1/3-octave- band corrections, dB (a)	1/3-octave-band center frequency, Hz	Octave- and 1/3-octave- band corrections, dB (a)
50	-30.2	1 000	0.0*
63	-26.2*	1 250	.6
80	-22.5	1 600	1.0
100	-19.1	2 000	1.2*
125	-16.1*	2 500	1.3
160	-13.4	3 150	1.2
200	-10.9	4 000	1.0*
250	-8.6*	5 000	.5
315	-6.6	6 300	-.1
400	-4.8	8 000	-1.1*
500	-3.2*	10 000	-2.5
630	-1.9	12 500	-4.3
800	-.8		

*Octave-band corrections are denoted by *.

EXAMPLE: An example of A-level calculation for 1/3-octave-band measurements of an air-craft flyover noise is shown in table AII. The noise spectrum is first corrected by the A-weighting response functions given in table AI.

In order to combine decibels, the corrected band levels are first converted to relative pressure squared by dividing by 10 and taking the antilog of the result as follows:

$$(\text{Relative pressure})^2 = \text{Antilog}_{10} \frac{\text{Corrected level}}{10} \quad (\text{A1})$$

The relative pressure squared is then summed and converted back to corresponding decibels:

$$L_A = 10 \log_{10} \sum_{i=1}^{25} (\text{Relative pressure})^2 \quad (\text{A2})$$

For the example in table AII, A-level = 103.3 dB(A).

APPENDIX A

**TABLE AII. - EXAMPLE OF A-LEVEL CALCULATION FROM 1/3-OCTAVE-BAND
MEASUREMENTS OF AIRCRAFT FLYOVER**

1/3-octave-band center frequency, Hz	Band level, dB	Correction for A-weighting (from table AI)	Corrected level, dB	(Relative pressure) ² , MPa
50	74.0	-30.2	43.8	0.023
63	76.0	-26.2	49.8	.095
80	73.0	-22.5	50.5	.112
100	66.0	-19.1	46.9	.049
125	77.0	-16.1	60.9	1.23
160	80.0	-13.4	66.6	4.57
200	85.0	-10.9	74.1	25.70
250	83.0	-8.6	74.4	27.54
315	76.0	-6.6	69.4	8.70
400	79.0	-4.8	74.2	26.30
500	79.0	-3.2	75.8	38.01
630	80.0	-1.9	78.1	64.56
800	80.0	-.8	79.2	83.18
1000	82.0	.0	82.0	158.49
1250	83.0	.6	83.6	229.08
1600	84.0	1.0	85.0	316.22
2000	89.0	1.2	90.2	1 047.12
2500	101.0	1.3	102.3	16 982.44
3150	90.0	1.2	91.2	1 318.25
4000	84.0	1.0	85.0	316.22
5000	87.0	.5	87.5	562.34
6300	77.0	-.1	76.9	48.97
8000	74.0	-1.1	72.9	19.49
10 000	61.0	-2.5	58.5	.708
				21 279.39

EQUIPMENT: (1) A sound level meter or equivalent equipment adhering to the standards
(ANSI, IEC)

or

(2) Equipment for determining octave-band or 1/3-octave-band noise measurements

REFERENCES: Schultz, Theodore J.: Noise Assessment Guidelines – Technical Background
(Technical Background for Noise Abatement in HUD's Operating Programs). HUD Rep.
No. TE/NA 172, Dec. 1971. (Available from NTIS as PB 210591.)

Natl. Bur. Stand.: Fundamentals of Noise: Measurement, Rating Schemes, and Standards.
NTID300.15, U.S. Environ. Prot. Agency, Dec. 31, 1971.

Young, Robert W.: Don't Forget the Simple Sound-Level Meter. NOISE Contr., vol. 4,
no. 3, May 1958, pp. 42-43.

APPENDIX B

D-WEIGHTED SOUND PRESSURE LEVEL

SCALE: D-level (DL , L_D)

UNIT: dB(D) (dB)

Reference pressure: $20 \mu\text{Pa}$

DEFINITION: D-weighted sound pressure level or D-level is sound pressure level which has been frequency filtered or weighted to reduce the effect of the low frequency noise and increase the effect of high frequency noise. D-level is measured in decibels with a standard sound level meter which contains a "D" weighting network with the response curve shown in figure B1.

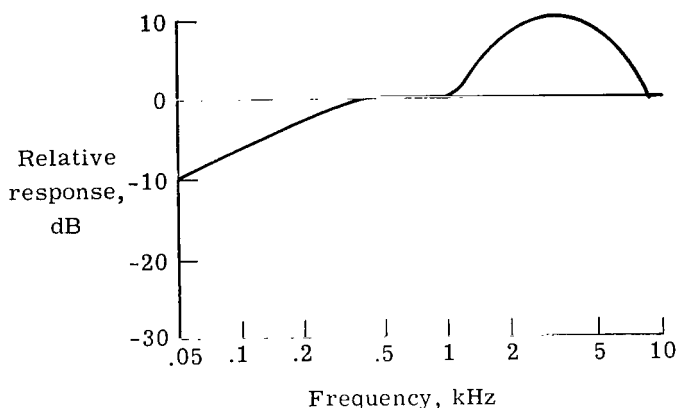


Figure B1.- D-weighting.

STANDARDS: A standardized D-weighting network is being considered for incorporation in "Precision Sound Level Meters," IEC Recomm. Publ. 179, Second ed., 1973.

Frequency Weighting Network for Approximation of Perceived Noise Level for Aircraft Noise. ARP 1080, Soc. Automot. Eng., Inc., July 1, 1969.

Octave, Half-Octave and Third-Octave Band Filters Intended for the Analysis of Sounds and Vibrations. IEC Recomm. Publ. 225, First ed., Int. Electrotech. Comm., 1966.

GEOGRAPHICAL USAGE: International

BACKGROUND: D-level is similar to A-level in that it attenuates the lower frequencies in a manner approximating the behavior of the human ear. However, D-level was intended to relate to the relative noisiness of broadband spectra while A-level was intended to relate to loudness. D-level replaced N-weighted sound level (N-level) which was a much earlier measure for estimating PNL.

The D-weighting network provides a frequency response comparable to the inverse 40-nyoy contour of equal annoyance. This network when incorporated into a sound level meter provides a simple approximation of the judged PNL for a variety of sounds. PNL can be estimated from the sound level reading of D-level by the following equation:

$$\text{PNL} \approx L_D + 7$$

APPENDIX B

Kryter (NASA CR 1636, 1970) proposes three different D-levels: D_1 , D_2 , and D_3 as means of estimating PNL. He notes that the D_2 -weighting is adjusted to take into account a relatively fewer number of critical bands below 355 Hz than above. It is recommended that D-level be used as an estimator for those sounds having their energy predominantly above 355 Hz.

CALCULATION METHOD: D-level can be determined by using a sound level meter that contains an electrical network for D-weighting. It also may be estimated by applying the D-weighting values (fig. B1, table BI) to octave or 1/3-octave frequency band measures and summing the bands on the basis of their squared pressures (often referred to as summation on an energy basis).

TABLE BI. - D-WEIGHTING CORRECTION FUNCTIONS

1/3-octave-band center frequency, Hz	Octave- and 1/3-octave- band corrections, dB (a)	1/3-octave-band center frequency, Hz	Octave- and 1/3-octave- band corrections, dB (a)
50	-12.8	1000	0.0*
63	-10.9*	1250	2.0
80	-9.0	1600	4.9
100	-7.2	2000	7.9*
125	-5.5*	2500	10.6
160	-4.0	3150	11.5
200	-2.6	4000	11.1*
250	-1.6*	5000	9.6
315	-.8	6300	7.6
400	-.4	8000	5.5*
500	-.3*	10000	3.4
630	-.5	12500	-1.4
800	-.6		

^aOctave-band corrections are denoted by *.

EXAMPLE: Use table BI and follow the procedure in the example for A-level (table AII).

EQUIPMENT: (1) A sound level meter or equivalent equipment with a D-weighting network adhering to the standards (IEC, SAE)

or

(2) Equipment for determining octave or 1/3-octave-band noise measurements

REFERENCES: Kryter, Karl D.: The Effects of Noise on Man. Academic Press, Inc., 1970.

Peterson, Arnold P. G.; and Gross, Ervin E., Jr.: Handbook of Noise Measurement. Seventh ed., General Radio Co., c.1972.

APPENDIX C

PERCEIVED NOISE LEVEL

SCALE: Perceived noise level (PNL, L_{PN})

UNIT: PNdB

DEFINITION: Perceived noise level (PNL) is rating of the noisiness of a sound signal calculated from acoustic measurements. PNL is computed from sound pressure levels measured in octave or 1/3-octave frequency bands. This rating is most accurate in estimating the perceived noisiness of broadband sounds of similar time duration which do not contain strong discrete frequency components.

STANDARDS: Definitions and Procedures for Computing the Effective Perceived Noise Level for Flyover Aircraft Noise. ARP 1071, Soc. Automot. Eng., Inc., June 1972.

Procedure for Describing Aircraft Noise Around an Airport. Second ed., R507, Int. Organ. Stand., June 1970.

Noise Standards: Aircraft Type Certification. Federal Aviation Regulations, vol. III, pt. 36, FAA, Dec. 1969.

GEOGRAPHICAL USAGE: International

BACKGROUND: PNL is patterned after loudness level except that equal noisiness curves are employed instead of equal loudness curves. Discrete frequency or impulsive type sounds are not within the scope of PNL. The numerical value of PNL was intended to represent the sound pressure level of an octave band of noise at 1000 Hz which would be judged to be equally as noisy as the sound to be rated. Equally noisy is intended to mean that in a comparison of sounds one would just as soon have or not have one noise as the other at his home during the day or night. Perceived noise level is measured in units of PNdB. These units are the translation of the subjective noy scale to a dB-type scale; an increase of 10 PNdB in a sound is equivalent to a doubling of its noy value.

CALCULATION METHOD: Two methods are available for determining PNL. One uses noy tables and is suitable for hand calculation; the other uses equations and is adapted for computer calculations.

I. PNL From Noy Tables

(1) The sound pressure level in each 1/3- (or full) octave band from 50 to 10 000 Hz is converted to a noy value (abbreviated N) by reference to table CI. One finds the proper value of noys, corresponding to each of the measured levels in the various 1/3-octave bands, by entering the table at the appropriate band center frequency.

TABLE CI. - NOYS AS A FUNCTION OF SOUND PRESSURE LEVEL

SPL	Noys, N_f for 1/3-octave-band center frequencies, Hz, of -																			
	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000
4																			0.10	
5																		0.10	.11	0.10
6																		.11	.12	.11
7																		.12	.14	.13
8																		.14	.16	.14
9																	0.10	.16	.17	.16
10																	.11	.17	.19	.18
11																	.13	.19	.22	.21
12																0.10	.14	.22	.24	.24
13																.11	.16	.24	.27	.27
14																.13	.18	.27	.30	.30
15														0.10	.14	.21	.30	.33	.33	.30
16									0.10	0.10	0.10	0.10	0.10	.11	.16	.24	.33	.35	.35	.33
17									.11	.11	.11	.11	.11	.13	.18	.27	.35	.38	.38	.35
18									0.10	.13	.13	.13	.13	.13	.15	.21	.30	.38	.41	.38
19									.11	.14	.14	.14	.14	.14	.17	.24	.33	.41	.45	.41
20									.13	.16	.16	.16	.16	.16	.20	.27	.36	.45	.49	.45
21							0.10	.18	.18	.18	.18	.18	.18	.23	.30	.39	.49	.53	.53	.49
22							.11	.16	.21	.21	.21	.21	.21	.21	.26	.33	.42	.53	.57	.53
23							.13	.18	.24	.24	.24	.24	.24	.24	.30	.36	.46	.57	.62	.57
24					0.10	.14	.21	.27	.27	.27	.27	.27	.27	.33	.40	.50	.62	.67	.67	.62
25					.11	.16	.24	.30	.30	.30	.30	.30	.30	.35	.43	.55	.67	.73	.73	.67
26					.13	.18	.27	.33	.33	.33	.33	.33	.33	.38	.48	.60	.73	.79	.79	.73
27					0.10	.14	.21	.30	.35	.35	.35	.35	.35	.41	.52	.65	.79	.85	.85	.79
28					.11	.16	.24	.33	.38	.38	.38	.38	.38	.45	.57	.71	.85	.92	.92	.85
29					.13	.18	.27	.35	.41	.41	.41	.41	.41	.41	.49	.63	.77	.92	1.00	.84
30				0.10	.14	.21	.30	.38	.45	.45	.45	.45	.45	.53	.69	.84	1.00	1.07	1.07	1.00
31				.11	.16	.24	.33	.41	.49	.49	.49	.49	.49	.57	.76	.92	1.07	1.15	1.15	1.07
32				.13	.18	.27	.36	.45	.53	.53	.53	.53	.53	.62	.83	1.00	1.15	1.23	1.23	1.15
33				.14	.21	.30	.39	.49	.57	.57	.57	.57	.57	.67	.91	1.07	1.23	1.32	1.32	1.23
34			0.10	.16	.24	.33	.42	.53	.62	.62	.62	.62	.62	.73	1.00	1.15	1.32	1.41	1.41	1.32
35			.11	.18	.27	.36	.46	.57	.67	.67	.67	.67	.67	.79	1.07	1.23	1.41	1.51	1.51	1.41
36			.13	.21	.30	.40	.50	.62	.73	.73	.73	.73	.73	.85	1.15	1.32	1.51	1.62	1.62	1.51
37			.15	.24	.33	.43	.55	.67	.79	.79	.79	.79	.79	.92	1.23	1.41	1.62	1.74	1.74	1.62
38			.17	.27	.37	.48	.60	.73	.85	.85	.85	.85	.85	1.00	1.32	1.51	1.74	1.86	1.86	1.74
39			0.10	.20	.30	.41	.52	.65	.79	.92	.92	.92	.92	1.07	1.41	1.62	1.86	1.99	1.99	1.86
40			.12	.23	.33	.45	.57	.71	.85	1.00	1.00	1.00	1.00	1.15	1.51	1.74	1.99	2.14	2.14	1.99
41			.14	.26	.37	.50	.63	.77	.92	1.07	1.07	1.07	1.07	1.23	1.62	1.86	2.14	2.29	2.29	2.14
42			.16	.30	.41	.55	.69	.84	1.00	1.15	1.15	1.15	1.15	1.32	1.74	1.99	2.29	2.45	2.45	2.29
43			.19	.33	.45	.61	.76	.92	1.07	1.23	1.23	1.23	1.23	1.41	1.86	2.14	2.45	2.63	2.63	2.45
44		0.10	.22	.37	.50	.67	.83	1.00	1.15	1.32	1.32	1.32	1.32	1.52	1.99	2.29	2.63	2.81	2.81	2.63
45		.12	.26	.42	.55	.74	.91	1.08	1.24	1.41	1.41	1.41	1.41	1.62	2.14	2.45	2.81	3.02	3.02	2.81
46		.14	.30	.46	.61	.82	1.00	1.16	1.33	1.52	1.52	1.52	1.52	1.74	2.29	2.63	3.02	3.23	3.23	3.02
47		.16	.34	.52	.67	.90	1.08	1.25	1.42	1.62	1.62	1.62	1.62	1.87	2.45	2.81	3.23	3.46	3.46	3.23
48		.19	.38	.58	.74	1.00	1.17	1.34	1.53	1.74	1.74	1.74	1.74	2.00	2.63	3.02	3.46	3.71	3.71	3.46
49	0.10	.22	.43	.65	.82	1.08	1.26	1.45	1.64	1.87	1.87	1.87	1.87	2.14	2.81	3.23	3.71	3.97	3.97	3.71

TABLE CI. - Continued

SPL	Noys, N, for 1/3-octave-band center frequencies, Hz, of -																							
	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
50	0.12	0.16	0.49	0.72	0.90	1.17	1.36	1.56	1.76	2.00	2.00	2.00	2.00	2.00	2.30	3.02	3.46	3.97	4.26	4.26	3.97	3.71	3.02	2.40
51	.14	.20	.55	.80	1.00	1.26	1.47	1.68	1.89	2.14	2.14	2.14	2.14	2.14	2.46	3.23	3.71	4.26	4.56	4.56	4.26	3.97	3.23	2.63
52	.18	.34	.62	.90	1.05	1.36	1.58	1.80	2.03	2.30	2.30	2.30	2.30	2.30	2.64	3.46	3.97	4.56	4.89	4.89	4.56	4.26	3.46	2.81
53	.21	.39	.70	1.00	1.18	1.47	1.71	1.94	2.17	2.46	2.46	2.46	2.46	2.46	2.83	3.71	4.26	4.89	5.24	5.24	4.89	4.56	3.71	3.02
54	.25	.45	.79	1.09	1.28	1.58	1.85	2.09	2.33	2.64	2.64	2.64	2.64	2.64	3.03	3.97	4.56	5.24	5.61	5.61	5.24	4.89	3.97	3.23
55	.30	.51	.89	1.18	1.38	1.71	2.00	2.25	2.50	2.83	2.83	2.83	2.83	2.83	3.25	4.26	4.89	5.61	6.01	6.01	5.61	5.24	4.26	3.46
56	.34	.59	1.00	1.29	1.50	1.85	2.15	2.42	2.69	3.03	3.03	3.03	3.03	3.03	3.48	4.56	5.24	6.01	6.44	6.44	6.01	5.61	4.56	3.71
57	.39	.67	1.09	1.40	1.63	2.00	2.33	2.61	2.88	3.25	3.25	3.25	3.25	3.25	3.73	4.89	5.61	6.44	6.90	6.90	6.44	6.01	4.89	3.97
58	.46	.77	1.18	1.53	1.77	2.15	2.51	2.81	3.10	3.48	3.48	3.48	3.48	3.48	4.00	5.24	6.01	6.90	7.39	7.39	6.90	6.44	5.24	4.26
59	.51	.87	1.29	1.66	1.92	2.33	2.71	3.03	3.32	3.73	3.73	3.73	3.73	3.73	4.29	5.61	6.44	7.39	7.92	7.92	7.39	6.90	5.61	4.56
60	.59	1.00	1.40	1.81	2.08	2.51	2.93	3.26	3.57	4.00	4.00	4.00	4.00	4.00	4.59	6.01	6.90	7.92	8.49	8.49	7.92	7.39	6.01	4.89
61	.67	1.10	1.53	1.97	2.26	2.71	3.16	3.51	3.83	4.29	4.29	4.29	4.29	4.29	4.92	6.44	7.39	8.49	9.09	9.09	8.49	7.92	6.44	5.24
62	.77	1.21	1.66	2.15	2.45	2.93	3.41	3.78	4.11	4.59	4.59	4.59	4.59	4.59	5.28	6.90	7.92	9.09	9.74	9.74	9.09	8.49	6.90	5.61
63	.87	1.32	1.81	2.34	2.65	3.16	3.69	4.06	4.41	4.92	4.92	4.92	4.92	4.92	5.66	7.39	8.49	9.74	10.4	10.4	9.74	9.09	7.39	6.01
64	1.00	1.45	1.97	2.54	2.88	3.41	3.98	4.38	4.73	5.28	5.28	5.28	5.28	5.28	6.06	7.92	9.09	10.4	11.2	11.2	10.4	9.74	7.92	6.44
65	1.11	1.60	2.15	2.77	3.12	3.69	4.30	4.71	5.08	5.66	5.66	5.66	5.66	5.66	6.50	8.49	9.74	11.2	12.0	12.0	11.2	10.4	8.49	6.90
66	1.22	1.75	2.34	3.01	3.39	3.98	4.64	5.07	5.45	6.06	6.06	6.06	6.06	6.06	6.96	9.09	10.4	12.0	12.8	12.8	12.0	11.2	9.09	7.39
67	1.35	1.92	2.54	3.28	3.68	4.30	5.01	5.46	5.85	6.50	6.50	6.50	6.50	6.50	7.46	9.74	11.2	12.8	13.8	13.8	12.8	12.0	9.74	7.92
68	1.49	2.11	2.77	3.57	3.99	4.64	5.41	5.88	6.27	6.96	6.96	6.96	6.96	6.96	8.00	10.4	12.0	13.8	14.7	14.7	13.8	12.8	10.4	8.49
69	1.65	2.32	3.01	3.88	4.33	5.01	5.85	6.33	6.73	7.46	7.46	7.46	7.46	7.46	8.57	11.2	12.8	14.7	15.8	15.8	14.7	13.8	11.2	9.09
70	1.82	2.55	3.28	4.23	4.69	5.41	6.31	6.81	7.23	8.00	8.00	8.00	8.00	8.00	9.19	12.0	13.8	15.8	16.9	16.9	15.8	14.7	12.0	9.74
71	2.02	2.79	3.57	4.60	5.09	5.84	6.81	7.33	7.75	8.57	8.57	8.57	8.57	8.57	9.85	12.8	14.7	16.9	18.1	18.1	16.9	15.8	12.8	10.4
72	2.23	3.07	3.88	5.01	5.52	6.31	7.36	7.90	8.32	9.19	9.19	9.19	9.19	9.19	10.6	13.8	15.8	18.1	19.4	19.4	18.1	16.9	13.8	11.2
73	2.46	3.37	4.23	5.45	5.99	6.81	7.94	8.50	8.93	9.85	9.85	9.85	9.85	9.85	11.3	14.7	16.9	19.4	20.8	20.8	19.4	18.1	14.7	12.0
74	2.72	3.70	4.60	5.94	6.50	7.36	8.57	9.15	9.59	10.6	10.6	10.6	10.6	10.6	12.1	15.8	18.1	20.8	22.3	22.3	20.8	19.4	15.8	12.8
75	3.01	4.06	5.01	6.46	7.05	7.94	9.19	9.85	10.3	11.3	11.3	11.3	11.3	11.3	13.0	16.9	19.4	22.3	23.9	23.9	22.3	20.8	16.9	13.8
76	3.32	4.46	5.45	7.03	7.65	8.57	9.85	10.6	11.0	12.1	12.1	12.1	12.1	12.1	13.9	18.1	20.8	23.9	25.6	25.6	23.9	22.3	18.1	14.7
77	3.67	4.89	5.94	7.66	8.29	9.19	10.6	11.3	11.8	13.0	13.0	13.0	13.0	13.0	14.9	19.4	22.3	25.6	27.4	27.4	25.6	23.9	19.4	15.8
78	4.06	5.37	6.46	8.33	9.00	9.85	11.3	12.1	12.7	13.9	13.9	13.9	13.9	13.9	16.0	20.8	23.9	27.4	29.4	29.4	27.4	25.6	20.8	16.9
79	4.49	5.90	7.03	9.07	9.76	10.6	12.1	13.0	13.6	14.9	14.9	14.9	14.9	14.9	17.1	22.3	25.6	29.4	31.5	31.5	29.4	27.4	22.3	18.1
80	4.96	6.48	7.66	9.85	10.6	11.3	13.0	13.9	14.6	16.0	16.0	16.0	16.0	16.0	18.4	23.9	27.4	31.5	33.7	33.7	31.5	29.4	23.9	19.4
81	5.48	7.11	8.33	10.6	11.3	12.1	13.9	14.9	15.7	17.1	17.1	17.1	17.1	17.1	19.7	25.6	29.4	33.7	36.1	36.1	33.7	31.5	25.6	20.8
82	6.06	7.81	9.07	11.3	12.1	13.0	14.9	16.0	16.9	18.4	18.4	18.4	18.4	18.4	21.1	27.4	31.5	36.1	38.7	38.7	36.1	33.7	27.4	22.3
83	6.70	8.57	9.87	12.1	13.0	13.9	16.0	17.1	18.1	19.7	19.7	19.7	19.7	19.7	22.6	29.4	33.7	38.7	41.5	41.5	38.7	36.1	29.4	23.9
84	7.41	9.41	10.7	13.0	13.9	14.9	17.1	18.4	19.4	21.1	21.1	21.1	21.1	21.1	24.3	31.5	36.1	41.5	44.4	44.4	41.5	35.7	31.5	25.6
85	8.19	10.3	11.7	13.9	14.9	16.0	18.4	19.7	20.8	22.6	22.6	22.6	22.6	22.6	26.0	33.7	38.7	44.4	47.6	47.6	44.4	41.5	33.7	27.4
86	9.05	11.3	12.7	14.9	16.0	17.1	19.7	21.1	22.4	24.3	24.3	24.3	24.3	24.3	27.9	36.1	41.5	47.6	51.0	51.0	47.6	44.4	36.1	29.4
87	10.0	12.1	13.9	16.0	17.1	18.4	21.1	22.1	24.0	26.0	26.0	26.0	26.0	26.0	29.9	38.7	44.4	51.0	54.7	54.7	51.0	47.6	38.7	31.5
88	11.1	13.0	14.9	17.1	18.4	19.7	22.6	24.3	25.8	27.9	27.9	27.9	27.9	27.9	32.0	41.5	47.6	54.7	58.6	58.6	54.7	51.0	41.5	33.7
89	12.2	13.9	16.0	18.4	19.7	21.1	24.3	26.0	27.7	29.9	29.9	29.9	29.9	29.9	34.3	44.4	51.0	58.6	62.7	62.7	58.6	54.7	44.4	36.1
90	13.5	14.9	17.1	19.7	21.1	22.6	26.0	27.9	29.7	32.0	32.0	32.0	32.0	32.0	36.8	47.6	54.7	62.7	67.2	67.2	62.7	58.6	47.6	38.7
91	14.9	16.0	18.4	21.1	22.6	24.3	27.9	29.9	31.8	34.3	34.3	34.3	34.3	34.3	39.4	51.0	58.6	67.2	72.0	72.0	67.2	62.7	51.0	41.5
92	16.0	17.1	19.7	22.6	24.3	26.0	29.9	32.0	34.2	36.8	36.8	36.8	36.8	36.8	42.2	54.7	62.7	72.0	77.2	77.2	72.0	67.2	54.7	44.4
93	17.1	18.4	21.1	24.3	26.0	27.9	32.0	34.3	36.7	39.4	39.4	39.4	39.4	39.4	45.3	58.6	67.2	77.2	82.7	82.7	77.2	72.0	58.6	47.6
94	18.4	19.7	22.6	26.0	27.9	29.9	34.3	36.8	39.4	42.2	42.2	42.2	42.2	42.2	48.5	62.7	72.0	82.7	88.6	88.6	82.7	72.0	62.7	51.0
95	19.7	21.1	24.3	27.9	29.9	32.0	36.8	39.4	42.2	45.3	45.3	45.3	45.3	45.3	52.0	67.2	77.2	88.6	94.9	94.9	88.6	82.7	67.2	54.7
96	21.1	22.6	26.0	29.9	32.0	34.3	39.4	42.2	45.3	48.5	48.5	48.5	48.5	48.5	55.7	72.0	82.7	94.9	102	102	94.9	88.6	72.0	58.6
97	22.6	24.3	27.9	32.0	34.3	36.8	42.2	45.3	48.5	52.0	52.0	52.0	52.0	52.0	59.7	77.2	88.6	102	109	109	102	94.9	77.2	62.7
98	24.3	26.0	29.9	34.3	36.8	39.4	45.3	48.5	52.0	55.7	55.7	55.7	55.7	55.7	64.0	82.7	94.9	109	117	117	109	102	82.7	67.2
99	26.0	27.9	32.0	36.8	39.4	42.2	48.5	52.0	55.7	59.7	59.7	59.7	59.7	59.7	68.6	88.6	102	117	125	125	117	109	88.6	72.0

TABLE CI. - Concluded

SPL	Noys, N, for 1/3-octave-band center frequencies, Hz, of -																							
	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
100	27.9	29.9	34.3	39.4	42.2	45.3	52.0	55.7	59.7	64.0	64.0	64.0	64.0	64.0	73.5	94.9	109	125	134	134	125	117	94.9	77.2
101	29.9	32.0	36.8	42.2	45.3	48.5	55.7	59.7	64.0	68.6	68.6	68.6	68.6	68.6	78.8	102	117	134	144	144	134	125	102	82.7
102	32.0	34.3	39.4	45.3	48.5	52.0	59.7	64.0	68.6	73.5	73.5	73.5	73.5	73.5	84.4	109	125	144	154	154	144	134	109	88.6
103	34.3	36.8	42.2	48.5	52.0	55.7	64.0	68.6	73.5	78.8	78.8	78.8	78.8	78.8	90.5	117	134	154	165	165	154	144	117	94.9
104	36.8	39.4	45.3	52.0	55.7	59.7	68.6	73.5	78.8	84.4	84.4	84.4	84.4	84.4	97.0	125	144	165	177	177	165	154	125	102
105	39.4	42.2	48.5	55.7	59.7	64.0	73.5	78.8	84.4	90.5	90.5	90.5	90.5	90.5	104	134	154	177	189	189	177	165	134	109
106	42.2	45.3	52.0	59.7	64.0	68.6	78.8	84.4	90.5	97.0	97.0	97.0	97.0	97.0	111	144	165	189	203	203	189	177	144	117
107	45.3	48.5	55.7	64.0	68.6	73.5	84.4	90.5	97.0	104	104	104	104	104	119	154	177	203	217	217	203	189	154	125
108	48.5	52.0	59.7	68.6	73.5	78.8	90.5	97.0	104	111	111	111	111	111	128	165	189	217	233	233	217	203	165	134
109	52.0	55.7	64.0	73.5	78.8	84.4	97.0	104	111	119	119	119	119	119	137	177	203	233	249	249	233	217	177	144
110	55.7	59.7	68.6	78.8	84.4	90.5	104	111	119	128	128	128	128	128	147	189	217	249	267	267	249	233	189	154
111	59.7	64.0	73.5	84.4	90.5	97.0	111	119	128	137	137	137	137	137	158	203	233	267	286	286	267	249	203	165
112	64.0	68.6	78.8	90.5	97.0	104	119	128	137	147	147	147	147	147	169	217	249	286	307	307	286	267	217	177
113	68.6	73.5	84.4	97.0	104	111	128	137	147	158	158	158	158	158	181	233	267	307	329	329	307	286	233	189
114	73.5	78.8	90.5	104	111	119	137	147	158	169	169	169	169	169	194	249	286	329	352	352	329	307	249	203
115	78.8	84.4	97.0	111	119	128	147	158	169	181	181	181	181	181	208	267	307	352	377	377	352	329	267	217
116	84.4	90.5	104	119	128	137	158	169	181	194	194	194	194	194	223	286	329	377	404	404	377	352	286	233
117	90.5	97.0	111	128	137	147	169	181	194	208	208	208	208	208	239	307	352	404	433	433	404	377	307	249
118	97.0	104	119	137	147	158	181	194	208	223	223	223	223	223	256	329	377	433	464	464	433	404	329	267
119	104	111	128	147	158	169	194	208	223	239	239	239	239	239	274	352	404	464	497	497	464	433	352	286
120	111	119	137	158	169	181	208	223	239	256	256	256	256	256	294	377	433	497	533	533	497	464	377	307
121	119	128	147	169	181	194	223	239	256	274	274	274	274	274	315	404	464	533	571	571	533	497	404	329
122	128	137	158	181	194	208	239	256	274	294	294	294	294	294	338	433	497	571	611	611	571	533	433	352
123	137	147	169	194	208	223	256	274	294	315	315	315	315	315	362	464	533	611	655	655	611	571	464	377
124	147	158	181	208	223	239	274	294	315	338	338	338	338	338	388	497	571	655	702	702	655	611	497	404
125	158	169	194	223	239	256	294	315	338	362	362	362	362	362	416	533	611	702	752	752	702	655	533	433
126	169	181	208	239	256	274	315	338	362	388	388	388	388	388	446	571	655	752	806	806	752	702	571	464
127	181	194	223	256	274	294	338	362	388	416	416	416	416	416	478	611	702	806	863	863	806	752	611	497
128	194	208	239	274	294	315	362	388	416	446	446	446	446	446	512	655	752	863	925	925	863	806	655	533
129	208	223	256	294	315	338	388	416	446	478	478	478	478	478	549	702	806	925	991	991	925	863	702	571
130	223	239	274	315	338	362	416	446	478	512	512	512	512	512	588	752	863	991	1062	1062	991	925	752	611
131	239	256	294	338	362	388	446	478	512	549	549	549	549	549	630	806	925	1062	1137	1137	1062	991	806	655
132	256	274	315	362	388	416	478	512	549	588	588	588	588	588	676	863	991	1137	1219	1219	1137	1062	863	702
133	274	294	338	388	416	446	512	549	588	630	630	630	630	630	724	925	1062	1219	1306	1306	1219	1137	925	752
134	294	315	362	416	446	478	549	588	630	676	676	676	676	676	776	991	1137	1306	1399	1399	1306	1219	991	806
135	315	338	388	446	478	512	588	630	676	724	724	724	724	724	832	1062	1219	1399	1499	1499	1399	1306	1062	863
136	338	362	416	478	512	549	630	676	724	776	776	776	776	776	891	1137	1306	1499	1606	1606	1499	1399	1137	925
137	362	388	446	512	549	588	676	724	776	832	832	832	832	832	955	1219	1399	1606	1721	1721	1606	1499	1219	991
138	388	416	478	549	588	630	724	776	832	891	891	891	891	891	1024	1306	1499	1721	1844	1844	1721	1606	1306	1062
139	416	446	512	588	630	676	776	832	891	955	955	955	955	955	1098	1399	1606	1844	1975	1975	1844	1721	1399	1137
140	446	478	549	630	676	724	832	891	955	1024	1024	1024	1024	1024	1176	1499	1721	1975			1975	1844	1499	1219
141	478	512	588	676	724	776	891	955	1024	1098	1098	1098	1098	1098	1261	1606	1844				1975	1606	1306	
142	512	549	630	724	776	832	955	1024	1098	1176	1176	1176	1176	1176	1351	1721	1975						1721	1399
143	549	588	676	776	832	891	1024	1098	1176	1261	1261	1261	1261	1261	1448	1844							1844	1499
144	588	630	724	832	891	955	1098	1176	1261	1351	1351	1351	1351	1351	1552	1975							1975	1606
145	630	676	776	891	955	1024	1176	1261	1351	1448	1448	1448	1448	1448	1664									1721
146	676	724	832	955	1024	1098	1261	1351	1448	1552	1552	1552	1552	1552	1783									1844
147	724	776	891	1024	1098	1176	1351	1448	1552	1664	1664	1664	1664	1664	1911									1975
148	776	832	955	1098	1176	1261	1448	1552	1664	1783	1783	1783	1783	1783	2048									
149	832	891	1024	1176	1261	1351	1552	1664	1783	1911	1911	1911	1911	1911										
150	891	955	1098	1261	1351	1448	1664	1783	1911	2048	2048	2048	2048	2048										

APPENDIX C

(2) These noy values are summed in the following manner:

Octave bands

$$N_t = n_{\max} + 0.3 \left(\sum_{i=1}^k n - n_{\max} \right) \quad (C1)$$

1/3-octave bands

$$N_t = n_{\max} + 0.15 \left(\sum_{i=1}^k n - n_{\max} \right) \quad (C2)$$

where

n_{\max} number of noys in band having greatest value

$\sum n$ sum of noy values in all bands

k = 24 for 1/3-octave bands
 = 8 for octave bands

(3) PNL in PNdB is then calculated from the formula

$$PNL = 40 + 33.22 \log N_t \quad (C3)$$

For N_t values of 1.0 or greater, the PNL can also be found from table CI by treating the quantity in the 1000-Hz column as the noy value and reading SPL as PNL.

II. PNL From Equations

The procedure for determining PNL with equations is the same as that used with noy tables except noy values are determined by equations as follows.

The value N , in noys, given in table CI for a particular frequency band is related to the band sound pressure level L by the following equation:

$$N = A \left[10^{M_j(L-L_k)} \right] \quad (N \leq 0.1; \quad L \geq 150) \quad (C4)$$

where M_j , L_k , and A depend upon the band center frequency and L , its magnitude, is shown in table CII.

For $L_1 \leq L < L_2$,

$$N = 0.1 \left[10^{M_1(L-L_1)} \right] \quad (0.1 \leq N \leq 0.3)$$

For $L_2 \leq L < L_3$,

$$N = 10^{M_2(L-L_3)} \quad (0.3 \leq N \leq 1.0)$$

APPENDIX C

For $L_3 \leq L < L_c$,

$$N = 10^{M_3(L-L_3)} \quad (1.0 \leq N_1; L \leq 150)$$

For $L_c \leq L \leq 150$,

$$N = 10^{M_4(L-L_4)}$$

Note that, for frequency bands having center frequencies from 400 to 6300 Hz, $L_3 = L_4$ and $M_3 = M_4$ (i.e., one set of values of L_k and M_j suffice to define any values for $N \leq 1$ and $L \leq 150$). The values of M_j and L_k are tabulated in table CII.

TABLE CII. - VALUES OF M_j AND L_k

Band center frequency, Hz	L_1	M_1	L_2	M_2	L_3	M_3	L_c	M_4	L_4
50	49	0.079520	55	0.058098	64	0.043478	91.01	0.030103	52
63	44	.068160	51	.058098	60	.040570	85.88	.030103	51
80	39	.068160	46	.052288	56	.036831	87.32	.030103	49
100	34	.059640	42	.047534	53	.036831	79.85	.030103	47
125	30	.053013	39	.043573	51	.035336	79.76	.030103	46
160	27	.053013	36	.043573	48	.033333	75.96	.030103	45
200	24	.053013	33	.040221	46	.033333	73.96	.030103	43
250	21	.053013	30	.037349	44	.032051	74.91	.030103	42
315	18	.053013	27	.034859	42	.030675	94.63	.030103	41
400	16	.053013	25	.034859	40	.030103	100.00	.030103	40
500	16	.053013	25	.034859	40	.030103	100.00	.030103	40
630	16	.053013	25	.034859	40	.030103	100.00	.030103	40
800	16	.053013	25	.034859	40	.030103	100.00	.030103	40
1000	16	.053013	25	.034859	40	.030103	100.00	.030103	40
1250	15	.059640	23	.034859	38	.030103	100.00	.030103	38
1600	12	.053013	21	.040221	34	.029960	100.00	.029960	34
2000	9	.053013	18	.037349	32	.029960	100.00	.029960	32
2500	5	.047712	15	.034859	30	.029960	100.00	.029960	30
3150	4	.047712	14	.034859	29	.029960	100.00	.029960	29
4000	5	.053013	14	.034859	29	.029960	100.00	.029960	29
5000	6	.053013	15	.034859	30	.029960	100.00	.029960	30
6300	10	.068160	17	.037349	31	.029960	100.00	.029960	31
8000	17	.079520	23	.037349	37	.042285	44.29	.029960	34
10000	21	.0596401	29	.043573	41	.042285	50.72	.029960	37

APPENDIX C

EXAMPLE:

PNL From Noy Tables

An example of PNL calculations by using an aircraft flyover noise spectrum is shown in table CIII where the 1/3-octave-band levels are tabulated and converted to noy values. With equation (C2) the total noy value is determined by

$$N_t = 134 + 0.15(604.63 - 134) = 204.59$$

Then the total noy value is converted to PNL in PNdB by

$$\text{PNL} = 40 + 33.22 \log 204.59 = 116.8 \text{ PNdB}$$

TABLE CIII. - EXAMPLE OF PNL CALCULATIONS FROM 1/3-OCTAVE-BAND
FREQUENCY FOR AIRCRAFT FLYOVER

1/3-octave-band center frequency, Hz	Band level, dB	Noy	1/3-octave-band center frequency, Hz	Band level, dB	Noy
50			800	80	16.00
63	76	4.46	1 000	82	18.40
80	73	4.23	1 250	83	22.60
100	66	3.01	1 600	84	31.50
125	77	8.29	2 000	89	51.00
160	80	11.30	2 500	101	134.00
200	85	18.40	3 150	90	67.20
250	83	17.10	4 000	84	44.40
315	76	11.00	5 000	87	51.00
400	79	14.90	6 300	77	23.90
500	79	14.90	8 000	74	15.80
630	80	16.00	10 000	61	5.24
					604.63

EQUIPMENT: (1) Tape recorder (necessary for single events)

(2) Sound level meter (IEC Standard)

(3) Octave- or 1/3-octave-band analyzer

(4) Digital computer optional

APPENDIX C

REFERENCES: Noise Standards: Aircraft Type Certification. Federal Aviation Regulations, vol. III, pt. 36, FAA, Dec. 1969.

Definitions and Procedures for Computing the Effective Perceived Noise Level for Flyover Aircraft Noise. ARP 1071, Soc. Automot. Eng., Inc., June 1972.

Procedure for Describing Aircraft Noise Around an Airport. Second ed., R507, Int. Organ. Stand., June 1970.

APPENDIX D

TONE-CORRECTED PERCEIVED NOISE LEVEL

SCALE: Tone-corrected perceived noise level (PNLT)

UNIT: PNdB

DEFINITION: Tone-corrected perceived noise level is perceived noise level (PNL) corrected for those 1/3-octave bands which contain discrete frequency components. Perceived noisiness of sounds which are of equal duration but which have pure tone characteristics can be compared using PNLT.

STANDARDS: Definitions and Procedures for Computing the Effective Perceived Noise Level for Flyover Aircraft Noise. ARP 1071, Soc. Automot. Eng., Inc., June 1972.

Procedure for Describing Aircraft Noise Around an Airport. Second ed., R507, Int. Organ. Stand., June 1970.

Noise Standards: Aircraft Type Certification. Federal Aviation Regulations, vol. III, pt. 36, FAA, Dec. 1969.

GEOGRAPHICAL USAGE: International

BACKGROUND: PNLT was developed in order to assess the added noisiness of discrete frequency components. An adjustment feature was added to PNL that increased its value when tones were present in the noise signal. The various methods used to compute PNLT all apply the tone correction to the perceived noise level in PNdB units. The method adopted by the FAA calculates the PNL of a sound and then adds a tone correction based on the total frequency and the amount that the tone exceeds the noise in the adjacent 1/3-octave bands.

Another method that was developed before the FAA method, but is not in widespread use at this time, adds the tone correction to the sound pressure level of the 1/3-octave band containing the prominent tone prior to the perceived noise level calculation. This method takes into consideration multiple tones rather than just the largest tone.

CALCULATION METHOD: In the FAA method, the PNL of a sound is calculated in the usual manner. The band spectra of the sound are examined to determine the presence of any pure tone components, which are specified in terms of a tone-background-noise ratio. If this ratio exceeds a certain level, a correction, in dB, is added to PNL for the sound. The magnitudes of the correction are a function of the tone-to-noise ratio and frequency of tone. Only one tone correction is added to the PNL of that sound, even though more than one pure tone might be present.

APPENDIX D

The following is a step-by-step procedure for calculating PNL_T:

Step 1:

Compute D_{ji} where

i 1/3-octave-band number

$j = i + 1$

$i = 1$ corresponds to band with center frequency of 80 Hz

L_i band sound pressure of i th frequency band

D_{ji} arithmetic difference between level L_i in frequency bands j and i

Step 2:

Encircle those values of D_{ji} where

$$|D_{ji} - D_{j-1,i-1}| > 5 \text{ dB}$$

Step 3:

If the encircled D_{ji} is positive and algebraically greater than $D_{j-1,i-1}$, encircle L_j .

If the encircled D_{ji} is zero or negative and $D_{j-1,i-1}$ is positive, encircle L_i .

Step 4:

For all nonencircled L_i , set $L'_i = L_i$.

For encircled L_i , set L'_i equal to the arithmetic average of L_{i-1} and L_{i+1} .^{*} If SPL in the highest frequency band is encircled, set $L'_{22} = L_{21} + D_{21,20}$.

Step 5:

Compute D_{ji} where

D'_{ji} arithmetic difference between levels L'_i in frequency bands j and i

Step 6:

Compute \bar{D}_{ji} as the arithmetic average of $D'_{j-1,i-1}$, D'_{ji} , and $D'_{j+1,i+1}$. Set $D'_{j-1,i-1}$ equal to D'_{ji} when $i = 1$, and set $D'_{j+1,i+1}$ equal to D'_{ji} when $i = 21$.

^{*}Recent experience has shown that this method of averaging the sound pressure levels of adjacent bands will result in too low a discrete frequency correction when the presence of a tone (or tones) influences the sound pressure levels of two adjacent bands. The procedure used in the study averaged the sound pressure levels of the two nearest noncircled adjacent bands rather than those of the two directly adjacent bands.

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Step 7:

Set \bar{L}_i equal to L_i' . Determine all other values of \bar{L}_j by adding \bar{D}_{ji} to \bar{L}_i .

Step 8:

Determine F_i where

$$F_i = L_i - \bar{L}_i$$

Step 9:

Determine the discrete frequency correction C from the following equations:

For 1/3-octave bands between 500 and 5000 Hz:

$$C = 0 \quad (F < 3)$$

$$C = \frac{F}{3} \quad (3 \leq F < 20)$$

$$C = 6.7 \quad (20 \leq F)$$

For all other 1/3-octave bands in the frequency range from 100 Hz to 10 000 Hz:

$$C = 0 \quad (F < 3)$$

$$C = \frac{F}{6} \quad (3 \leq F < 20)$$

$$C = 3.3 \quad (20 \leq F)$$

Step 10:

The maximum value of C determined in step 9 defines the discrete frequency correction which should be added to the value for PNL to obtain $PNLT$.

EXAMPLE: An example of $PNLT$ calculation for an aircraft flyover noise with a PNL of 104.6 PNdB is illustrated in table DI. The numbers at the top of each column correspond to the step number in the calculation procedure. Tone correction is added to PNL which is calculated in the normal manner to determine $PNLT$. Thus $PNLT = 104.6 + 2 = 106.6$ PNdB.

REFERENCES: Noise Standards: Aircraft Type Certification. Federal Aviation Regulations, vol. III, pt. 36, FAA, Dec. 1969.

Definitions and Procedures for Computing the Effective Perceived Noise Level for Flyover Aircraft Noise. ARP 1071, Soc. Automot. Eng., Inc., June 1972.

Procedure for Describing Aircraft Noise Around an Airport. Second ed., R507, Int. Organ. Stand., June 1970.

APPENDIX D

TABLE DI. - ILLUSTRATION OF THE USE OF FAA TONE CORRECTION
PROCEDURE DESCRIBED IN CALCULATION STEPS 1 TO 10^a

Band i	f _i	3	1 + 2	4	5	6	7	8	9
		L _i	D _{ji}	L _i	D _{ji}	D _{ji}	L _i	F _i	C
1	80	70		70			70	--	$\frac{2}{3}$
2	100	62	-8	62	-8	$-2\frac{1}{3}$	$67\frac{2}{3}$	--	
3	125	(70)	(+8)	(71)	+9	$+3\frac{1}{3}$	71	--	
4	160	80	+10	80	+9	$+6\frac{2}{3}$	$77\frac{2}{3}$	$2\frac{1}{3}$	
5	200	82	(+2)	82	+2	$+2\frac{2}{3}$	$80\frac{1}{3}$	$1\frac{2}{3}$	
6	250	(83)	+1	(79)	-3	$-1\frac{1}{3}$	79	(4)	
7	315	76	(-7)	76	-3	$-1\frac{1}{3}$	$77\frac{2}{3}$	--	
8	400	(80)	(+4)	(78)	+2	$+\frac{1}{3}$	78	2	
9	500	80	0	80	+2	+1	79	1	
10	630	79	-1	79	-1	0	79	--	
11	800	78	-1	78	-1	0	79	--	
12	1000	80	+2	80	+2	$-\frac{1}{3}$	$78\frac{2}{3}$	$1\frac{1}{3}$	
13	1250	78	-2	78	-2	$-\frac{2}{3}$	78	--	
14	1600	76	-2	76	-2	$-\frac{1}{3}$	$77\frac{2}{3}$	--	
15	2000	79	+3	79	+3	$+\frac{1}{3}$	78	1	
16	2500	(85)	+6	(79)	0	+1	79	(6)	
17	3150	79	(-6)	79	0	$-\frac{1}{3}$	$78\frac{2}{3}$	$\frac{1}{3}$	
18	4000	78	-1	78	-1	$-2\frac{2}{3}$	76	2	
19	5000	71	(-7)	71	-7	$-6\frac{1}{3}$	$69\frac{2}{3}$	$1\frac{1}{3}$	
20	6300	60	-11	60	-11	-8	$61\frac{2}{3}$	--	
21	8000	54	-6	54	-6	$-8\frac{2}{3}$	53	1	
22	10000	45	-9	45	-9	-8	45	--	

^aAccording to step 10, the discrete frequency correction is 2.
Thus, PNLT = 104.6 + 2 = 106.2 PNdB.

APPENDIX E

EFFECTIVE PERCEIVED NOISE LEVEL

SCALE: Effective perceived noise level ($EPNL$, L_{EPN})

UNIT: $EPNdB$ ($PNdB$)

DEFINITION: Effective perceived noise level is a single-number measure of complex aircraft flyover noise which approximates laboratory annoyance responses. It is derived from PNL , but it includes correction terms for the duration of an aircraft flyover and for the presence of audible pure tones or discrete frequencies (such as the whine of a jet aircraft) in the noise signal.

STANDARDS: Definitions and Procedures for Computing the Effective Perceived Noise Level for Flyover Aircraft Noise. ARP 1071, Soc. Automot. Eng., Inc., June 1972.

Procedure for Describing Aircraft Noise Around an Airport. Second ed., R507, Int. Organ. Stand., June 1970.

Noise Standards: Aircraft Type Certification. Federal Aviation Regulations, vol. III, pt. 36, FAA, Dec. 1969.

GEOGRAPHICAL USAGE: International

BACKGROUND: Although there are several methods of determining $EPNL$, all include both duration and tone corrections. The tone correction factor increases the magnitude of PNL to account for the increased noisiness of audible discrete frequency components such as are found in aircraft flyover noise. The duration correction increased the magnitude of PNL in an attempt to account for the increased noisiness of sounds of long duration. Effective perceived noise level, in $EPNdB$ units, is usually obtained by first determining a time sequence of tone-corrected perceived noise levels ($PNLT$) from 1/3-octave-band noise spectra. $EPNL$ is then determined by summing (on an energy basis) the tone-corrected $EPNL$ in 0.5-second time segments.

CALCULATION METHOD: $EPNL$ expressed in $EPNdB$ is determined as follows:

(1) SPL for each of the twenty-four 1/3-octave bands having a center frequency from 50 to 10 000 Hz is measured for a continuous sequence of 0.5-second time intervals (i in the subscript designates the sequence number of the 0.5-second interval) throughout the time period of the flyover noise.

(2) PNL is computed for every 1/3-octave band calculated at each 0.5-second (or i th) time interval defined within the duration interval. (See PNL , appendix C.)

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(3) Audible discrete frequencies are detected and tone corrections are determined for these frequencies. (See PNL_T, appendix D.)

(4) PNL_T is calculated by adding tone corrections T determined in step (3) to the perceived noise level at 0.5-second (or i th) interval (step (2)). Thus

$$(\text{PNLT})_i = (\text{PNL})_i + T_i \quad (\text{E1})$$

(5) The computation formula for effective perceived noise level in EPNdB is

$$\text{EPNL} = 10 \log \left[\sum_{i=0}^d \text{antilog} \frac{(\text{PNLT})_i}{10} \right] - 13 \quad (\text{E2})$$

Remember that PNL_T is computed from 1/3-octave-band sound pressure levels determined at discrete 0.5-second (or i th) intervals. The summation process noted in the formula extends over the duration d of the noise which is defined as the seconds between the first and last values of tone-corrected PNL which are a minimum of 10 dB down from maximum PNL_T. (See PNL_T, appendix D.)

EXAMPLE: Table EI shows an example of the EPNL calculation procedure, given PNL_T as a function of time, for an aircraft flyover as calculated by the following equation:

$$\text{EPNL} = 10 \log (167\,768.34 \times 10^6) - 13 = 99.2 \text{ EPNdB}$$

EQUIPMENT: (1) Tape recorder (necessary for single events)

(2) Sound level meter (IEC Standard)

(3) 1/3-octave-band real time analyzer

or

(4) 1/3-octave-band analyzer plus graphic level recorder

REFERENCES: Noise Standards: Aircraft Type Certification. Federal Aviation Regulations, vol. III, pt. 36, FAA, Dec. 1969.

Natl. Bur. Stand.: Fundamentals of Noise: Measurement, Rating Schemes, and Standards. NTID300.15, U.S. Environ. Prot. Agency, Dec. 31, 1971.

Definitions and Procedures for Computing the Effective Perceived Noise Level for Flyover Aircraft Noise. ARP 1071, Soc. Automot. Eng., Inc., June 1972.

Procedure for Describing Aircraft Noise Around an Airport. Second ed., R507, Int. Organ. Stand., June 1970.

Pearsons, Karl S.; and Bennett, Ricarda L.: The Effects of Temporal and Spectral Combinations on the Judged Noisiness of Aircraft Sounds. FAA-NO-69-3, June 1969.

APPENDIX E

TABLE EI. - EXAMPLE OF EPNL CALCULATION
FOR AIRCRAFT FLYOVER NOISE

Time, sec	PNLT	Antilog $\frac{\text{PNLT}}{10}$
6.0	82.8	
6.5	82.9	
7.0	83.1	
7.5	84.9	
8.0	86.9	
8.5	87.6	
9.0	87.7	
9.5	89.6	
10.0	88.9	
10.5	90.3	
11.0	93.0	1995.26×10^6
11.5	94.8	3 019.95
12.0	97.3	5 370.32
12.5	100.8	12 022.64
13.0	101.9	15 488.17
13.5	103.0	19 952.62
14.0	103.2	20 892.96
14.5	103.8	23 988.32
15.0	102.7	18 620.87
15.5	101.5	14 125.38
16.0	100.2	10 471.29
16.5	98.2	6 606.93
17.0	97.4	5 495.41
17.5	96.4	4 365.16
18.0	95.2	3 311.31
18.5	93.1	2 041.74
19.0	92.9	
19.5	91.6	
20.0	90.3	
Total		$167\,768.34 \times 10^6$

APPENDIX F

NOISE EXPOSURE FORECAST

INDEX: Noise exposure forecast (NEF)

UNIT: dB like unit

DEFINITION: Noise exposure forecast (NEF) is the total summation (on an energy basis) over a 24-hour period (weighted for the time of day) of effective perceived noise level (EPNL) minus the constant 88 dB. An illustrated approximation of NEF contours for runways at a major airport is shown in figure F1.

STANDARDS: None

GEOGRAPHICAL USAGE: United States

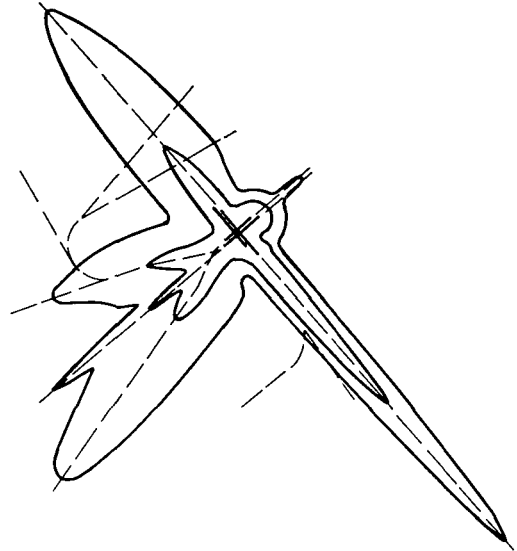


Figure F1. - NEF contours.

BACKGROUND: The noise exposure forecast uses EPNL as its basic noise measure for aircraft flyovers. EPNL together with the number of operations during the daytime (0700 to 2200) and nighttime (2200 to 0700) provide the information necessary to determine NEF at some specified location. As the number of events increases, NEF becomes larger.

Because of the added disturbance of nighttime versus the daytime operations, the noise of each night event effectively increases in the calculation procedure by 10 dB. That is, for the same average number of aircraft operations per hour during the daytime and nighttime periods, the NEF value for nighttime operation would be 10 dB higher than for daytime operations. For ease in determining NEF for known aircraft types, tables and graphs showing EPNL plotted against distance are available (FAA-NO-70-8).

The noise exposure forecasts around a given airport are lowered in absolute value by subtraction of a constant (88) to avoid confusion with CNR, CNEL, and other multiple-event indexes. An example of NEF contours for a typical airport configuration is shown in figure F1.

CALCULATION METHOD: The total noise exposure at a given point is viewed as composed of noise produced by different aircraft flying different flight paths. For specific class of aircraft i on flight path j , the $(NEF)_{ij}$ can be expressed as follows:

$$(NEF)_{ij} = (EPNL)_{ij} + 10 \log [N_{d,ij} + 16.67(N_{n,ij})] - 88 \quad (F1)$$

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where

i aircraft class

j flight path

$N_{d,ij}$ number of daytime (0700 to 2200) events for aircraft class i on flight path j

$N_{n,ij}$ number of nighttime (2200 to 0700) events for aircraft class i on flight path j

The total NEF at a given ground position is determined by summation of all the individual $(NEF)_{ij}$ values on an energy basis as follows:

$$NEF = 10 \log \sum_i \sum_j \text{antilog} \frac{(NEF)_{ij}}{10} \quad (F2)$$

EXAMPLE: An example for one $(NEF)_{ij}$ point using equation (F1) is as follows:

$$(EPNL)_{ij} = 90 \text{ EPNdB}$$

$$N_{d,ij} = 30$$

$$N_{n,ij} = 4$$

$$(NEF)_{ij} = 90 + 10 \log [30 + 16.67(4)] - 88 = 21.85$$

Computations showing the calculations involving the total NEF value using equation (F2) i.e., a sum of $(NEF)_{ij}$ values are as follows:

$$(NEF)_1 = 21.85$$

$$(NEF)_2 = 19.71$$

$$(NEF)_3 = 23.36$$

$$NEF = 10 \log \left(\text{antilog} \frac{21.85}{10} + \text{antilog} \frac{19.71}{10} + \text{antilog} \frac{23.36}{10} \right)$$

$$NEF = 10 \log (153.1 + 93.5 + 216.8) = 10 \log (463.4) = 26.7$$

EQUIPMENT: (1) No equipment is necessary. NEF contours can be drawn using EPNL levels for different classes of aircraft along with the proposed volume of operations.

(2) In the interest of economizing time and money a high-speed digital computer is recommended.

APPENDIX F

- REFERENCES: Bishop, Dwight E.; and Simpson, Myles A.: Noise Exposure Forecast Contours for 1967, 1970 and 1975 Operations at Selected Airports. FAA-NO-70-8, Sept. 1970.
- Bishop, Dwight E.; and Horonjeff, Richard D.: Noise Exposure Forecast Contour Interpretations of Aircraft Noise Tradeoff Studies. FAA-NO-69-2, May 1969. (Available from DDC as AD 695 507.)

APPENDIX G

DAY-NIGHT LEVEL

INDEX: Day-night level (L_{dn})

UNIT: dB

DEFINITION: Day-night level L_{dn} is the average (i.e., on an energy basis) A-weighted noise level integrated over a 24-hour period. Appropriate weightings are applied for the noise levels occurring in the daytime and nighttime periods.

STANDARDS: None

GEOGRAPHICAL USAGE: United States

BACKGROUND: Day-night level (L_{dn}) was developed as a single-number measure of community noise exposure. It was designed to improve upon equivalent sound level (L_{eq}) by adding a correction for nighttime noise intrusions. A 10-dB correction is applied to nighttime (2200 to 0700) sound levels to account for the increased annoyance to noise during the night hours. The L_{dn} uses the same energy equivalent concept as L_{eq} , which is defined as representing a fluctuating noise level in terms of a steady-state noise having the same energy content. The specified time integration period is for 24 hours. Again, like L_{eq} there is no stipulation of a minimum noise sampling threshold.

The noise level is measured in A-weighted sound pressure level. However, other weighting functions may be better for evaluating the effect of noise on human annoyance (i.e., D-level).

L_{dn} was not designed as a single source measure, and therefore it does not account adequately of tonal components or impulse noise. It is recommended that this measure not be used in determining source standards or for certification of product noise. Essentially, day-night level was introduced as a simple method for predicting the effects on a population of the average long-term exposure to environmental noise.

Recommended L_{dn} levels of 55 to 60 dB are projected as the long range goal for maximum permissible average sound level with respect to health and welfare. Results from test data indicated that an outdoor L_{dn} of approximately 60 dB or less is required in order that no more than 23 percent of the population exposed to noise would be highly annoyed.

CALCULATION METHOD: L_{dn} can be determined by two different methods:

(1) Continuous integration:

For continuous time integration of A-weighted sound level for a 24-hour period (86 400 seconds), the formula is

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$$L_{dn} = 10 \log \left\{ \frac{\int_0^{86400} w(t) \text{antilog} [L_A(t)/10] dt}{86400} \right\} \quad (G1)$$

where

w time of day weighting factor (from 0700 to 2200, $w = 1$; from 2200 to 0700, $w = 10$)

t time in seconds

$L_A(t)$ instantaneous A-level at time t

dt = Δt as it approaches 0

86 400 number of seconds in a day

(2) Temporal sampling:

For discrete sampling of A-weighted sound level for a 24-hour time period, the formula is

$$L_{dn} = 10 \log \left[\frac{\sum_{i=1}^n w_i \text{antilog} (L_{A,i}/10)}{n} \right] \quad (G2)$$

where

w_i time of day weighting factor for sample i (see eq. (G1))

$L_{A,i}$ A-level for sample i (for sounds with time varying fluctuations use L_{eq})

n number of samples of L_A in a 24-hour period (or L_{eq} for specified periods of time within 24 hours)

EXAMPLE: The following example illustrates one method of determining L_{dn} . These three samples are equivalent sound level (L_{eq}) over specified time periods.

Temporal sampling (for 24 hours):

Table GI gives the measured L_{eq} for eight 3-hour samples during a 24-hour period. The weighting factors for time of day and night have been applied and the day-night sound level is

APPENDIX G

$$L_{dn} = 10 \log \left(\frac{273.5 \times 10^6}{8} \right) = 10 \log (34.18 \times 10^6) = 75.3 \text{ dB}$$

TABLE GI.- EXAMPLE OF CALCULATION FOR L_{dn}

Time	n	L_{eq} , dB	Antilog	Weighting factor, w
0700 to 1000	1	71	12.0×10^6	1
1000 to 1300	2	75	31.0	1
1300 to 1600	3	70	10.0	1
1600 to 1900	4	73	20.0	1
1900 to 2200	5	70	10.0	1
2200 to 0100	6	70	10.0×10^6	10
0100 to 0400	7	65	3.2	10
0400 to 0700	8	68	6.3	10

EQUIPMENT: Continuous sampling:

Special monitoring equipment capable of integrating sound levels for long periods of time

Temporal sampling:

- (1) Sound level meter (IEC Standard)
- (2) Graphic level recorder
- (3) Tape recorder
- (4) Statistical distribution analyzer

REFERENCES: Office of Noise Abatement and Control: Information on Levels of Environmental Noise Requisite To Protect Public Health and Welfare With an Adequate Margin of Safety. 550/9-74-004, U.S. Environ. Prot. Agency, Mar. 1974.

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APPENDIX H

AIRCRAFT SOUND DESCRIPTION SYSTEM AND SITUATION INDEX

INDEX: Aircraft sound description system (ASDS)

Situation index (SI)

UNIT: For ASDS, minutes

For SI, acre-minute ($\text{meter}^2\text{-minute}$)

DEFINITION: Aircraft sound description system (ASDS) is the total amount of time that aircraft noise levels exceed 85 dB(A) over a specified interval of time.

Situation index (SI) is a single number representation, incorporating both time and area, of the overall noise exposure in excess of 85 dB(A).

STANDARDS: Required by FAA for all noise exposure analyses conducted by or submitted to the agency.

Aircraft Sound Description System. Order 7040.2, FAA, Aug. 10, 1973.

GEOGRAPHICAL USAGE: United States

BACKGROUND: The aircraft sound description system was developed by the Federal Aviation Administration for the purpose of establishing a "uniform, practical, technically adequate, and understandable method for describing aircraft noise exposure."

The FAA order referred to states the reasoning which led to the development of ASDS:

"In order to provide a noise exposure statement flexible enough to accommodate the potentially wide variety of viewpoints and levels of technical background in the community, as well as to permit a broader and more active participation in noise abatement effort by community leaders, airport and airline officials, as well as all levels of government, it was concluded that two essential conditions had to be satisfied. First of these conditions was that noise exposure analyses had to be improved in objectivity by avoiding subjective pre-judgments in the calculating procedures; second, noise exposure analyses had to be presented in units understandable by both those exposed to aircraft noise and those responsible for efforts to abate it. These conditions are not satisfied by techniques presently in use.

"In view of the above, a method entitled the 'Aircraft Sound Description System' was developed for agency use. The principal feature of the Aircraft Sound Description System is that it states noise exposure in terms of the total amount of time that noise levels exceed a preselected threshold level at various locations relative to the airport. The method is presented in FAA Report FAA-EQ-73-3, 'Aircraft Sound Description System, Background and Application,' dated March 1973."

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CALCULATION METHOD: The ASDS can be computed manually for a limited number of aircraft operations. For airports with large numbers of flights the data handling and computations required can become too cumbersome to be done manually and are best performed by computer.

The following list is the information required and the necessary steps for the manual calculation of ASDS. The computer routine would utilize the same steps except that the contour location points would be stored in computer memory rather than plotted on a map.

Required information:

Maps of the land area under study

A layout of the airport runways

A layout of the ground tracks followed by the aircraft for departures and approaches

A list of all operations on each runway including the aircraft type and its take-off or landing weight

Calculation steps:

- (1) List operations data
- (2) Select 85 dB(A) contours corresponding to aircraft operations listed in step (1)
- (3) Draw map of runway orientation
- (4) Add ground tracks to map
- (5) Match aircraft operations with appropriate ground tracks
- (6) Draw contours onto map layout for all aircraft and all operations
- (7) Sequentially number the zones which are produced by the overlapping of the separate contours
- (8) Identify all the aircraft contours which overlap each zone
- (9) Calculate the total exposure time of each zone; the exposure time for each operation is assumed to be 15 seconds for take-offs and 10 seconds for landings
- (10) Calculate SI as the product of the total time of exposure within each contour and area within the contour.

EXAMPLE: The ASDS calculation is an involved procedure and presenting an example is beyond the scope of this paper. A very thorough treatment of the calculation and an example problem are contained in FAA-EQ-74-2, II and, therefore, will not be repeated here.

EQUIPMENT: (1) No equipment is necessary. The 85 dB(A) contours for various classes of aircraft are needed; these are contained in FAA-EQ-74-2, III.

(2) For cases involving a large number of operations a high-speed digital computer is required for the data handling and detailed computations.

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